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Forthcoming Events.

APRIL 12.

British Foundrymen's Association: London Branch.—"Cupola Blowing and Efficient Combustion," by Alexander Hayes.

APRIL 13.

British Foundrymen's Association: East Midlands Branch.—Visit to Technical Institute, Loughborough, and Annual Meeting. "Training of Apprentices," by H. Schofield, A.M.Inst.C.E.

APRIL 27.

British Foundrymen's Association: Newcastle Branch.—"Some Foundry Problems," by J. Shaw.

MAY 4.

British Foundrymen's Association: Lancashire Branch.—Annual meeting and election of officers.

NOTES AND COMMENTS.

Metal Production under War Conditions.

The report of the War Cabinet for the year 1917, which was published last month, reminds us that the primary task of the Ministry of Munitions in relation to iron and steel has been to increase domestic production by bringing into operation every available blast furnace, by hastening the construction of new furnaces now building—of which there is a considerable number—by increasing the utilisation of domestic ores for the production of pig-iron suitable for steel manufacture, and by the extension of steel works for the treatment of such material on an increased scale. From new blast furnaces and extensions to plant an ultimate increase of pig-iron production is anticipated which will increase the output by one-fifth. As the outcome of these developments it is estimated that, by the end of 1918, the national capacity for steel production will have been increased by more than 50 per cent. The current home production of steel is distributed with the utmost care among the various requirements of the army, the navy and the shipyards, leaving for other miscellaneous war and civilian needs only 11 per cent. of the total supply. There is in addition the steel received from America, all of which is devoted to war purposes. The output of high-speed steel, which before the war was 6,500 tons per annum, has been increased to approximately 15,000 tons per annum.

A special department of the Ministry was established in March, 1917, to assist in increasing the output of non-ferrous minerals within the United Kingdom. This Department has already laid the foundation for many developments. As regards the rationing of industry, during the past year the activities of the Ministry of Munitions have been very largely concentrated on the problem of satisfying the growing demand for steel and other industrial metals. The problem is two-fold; on the one hand, that of providing increasing supplies; and, on the other hand, that of allocating them among rival users in the manner directed by national policy while securing the most efficient technical utilisation and developing to the full all possible economies in consumption. Strict official regulation is now applied to the distribution and consumption of industrial metals. Substantial economies have been effected both in regard to the weight of metal required for the production of a particular component, the substitution of second-hand and scrap metal for virgin metal wherever possible, and the development of new alloys. Successful endeavours have also been made to substitute cast iron for brass for certain components of gun ammunition. The output under the care of the Ministry has increased to such an extent that it is now possible to meet all essential requirements from home production. The production of spelter in the United Kingdom has been more than doubled as compared with the pre-war standard, and it is anticipated that developments

now in hand will make the country permanently self-supporting to the extent of 75 per cent. of its pre-war requirements.

As to scrap metals and salvage, in February, 1917, a special organisation was set up in the Ministry to deal with responsibility for supervising the collection of all scrap metal within the control of Government departments, increasing the salvage of metal components and scrap metals from the Front and bringing into use any dormant supplies of scrap metal within the country. A very large accumulation of ferrous scrap has been absorbed, and much non-ferrous scrap has been collected from munition factories and elsewhere. The importance of these economies is indicated by the fact that in the case of brass manufacture about 50 per cent. of the metal employed is returnable as scrap or swarf.

The Non-Ferrous Metal Industry.

As was recently announced, the President of the Board of Trade has appointed Sir Dudley Stewart Smith, K.C. (chairman), Sir Harold Elverston, M.P., and Mr. H. J. Mackinder, M.P., to be a committee to examine all applications for licences under the Non-Ferrous Metal Industry Act, 1918, and to report to the Board of Trade thereon.

The following rules have been made by the Board of Trade, with the concurrence of the Treasury, under Section 6 of the Non-Ferrous Metal Industry Act, 1918.

There shall be excluded from dealings by way of wholesale trade within the meaning of the Act, dealings in quantities below the following limits :—

Zinc	...	25	tons
Copper	...	25	,,
Tin	...	5	,,
Lead	...	25	,,
Nickel	...	5	,,
Aluminium		5	,,

} During any one quarter of the year ending 31st March, 30th June, 30th September, 31st December.

in the raw materials of usual commercial shapes or the equivalent in forms of ores or concentrated material.

The expression "Metal" includes metal in any form as it leaves the furnace or refinery being unwrought, also scrap and swarf of all sorts for re-melting. The fee for a licence is one guinea, which will be returned to the applicant if the licence is refused.

An application for a licence is to be made to the Board of Trade in writing, and should be accompanied by Form 1 in the Schedule. The Board of Trade will not refuse a licence to a company, firm or individual to which any of the conditions in the First Schedule of the Act apply, nor will they revoke or suspend a licence without giving notice in writing to the holder, so as to allow him twenty-one days for an inquiry. Any person to whom such notice is given must within fourteen days send to the Board of Trade a notice of application for a hearing on Form 2A or 2B of the Schedule.

The name of any company, firm or individual to whom a licence has been granted under the Act, or whose licence has been suspended or revoked, will be published as soon as practicable in the London, Edinburgh or Dublin "Gazettes," and in the "Board of Trade Journal." An order of the Board of Trade applying the Act to any non-ferrous metals and ores not mentioned in the Act will be published in the same journals at least one month before it comes into effect.

Applications for licences should be addressed to the Assistant Secretary, Department of Industries and Manufactures, Board of Trade, Gwydyr House, Whitehall, London, S.W.1, and should be accompanied by a remittance of £1 1s., made payable to the Accountant-General, Board of Trade. Copies of the Forms 1, 2A, and 2B can be obtained at this address.

Iron and Steel Institute.

Programme of Annual Meeting.

Mr. G. C. Lloyd (Secretary) has issued the following programme of proceedings at the forthcoming annual meeting of the Iron and Steel Institute, which will be held in the House of the Institution of Civil Engineers, Great George Street, Westminster, on Thursday and Friday, May 2 and 3:—

Thursday, May 2.

General meeting at 10.30 a.m., when the Council will present their Report for 1917, and the Hon. Treasurer the statement of accounts. Scrutineers will be appointed for the examination of voting papers for election of new members and associates of the Institute.

The retiring President will induct into the Chair the President-Elect (Mr. Eugène Schneider). The award of the Bessemer Medal for 1918 will be made to Sir William Beardmore, Bart. (Past President). The President will then deliver his Inaugural Address, following which a selection of Papers will be read and discussed.

At 1 p.m. the meeting will be adjourned.

Friday, May 3.

At 10 a.m. the general meeting will be resumed, when the award of grants from the Andrew Carnegie Research Fund in aid of research work will be announced, following which a further selection of Papers will be read and discussed. Those Papers for which time cannot be found will be taken as read and discussed by correspondence. Afternoon sessions will also probably be held.

The list of Papers expected to be submitted is given below, but it is possible that the publication of some of them may be restricted by the Censor.

Papers.

"Practical Points affecting Yield and Efficiency of Blast Furnace," Report of the Blast Furnace Committee; "Importance of Coke Hardness," by G. D. Cochrane; "Economic Value of the Jurassic Iron Ores of Great Britain," by Dr. F. H. Hatch; "Fuel Economy in Blast Furnaces," by T. C. Hutchinson; "Economy in Gas Cleaning," by A. Lennox Leigh; "Potash Recovery from Blast Furnaces," by Kenneth Chance; "Manufacture of Portland Cement from Blast-Furnace Slag," by E. H. Lewis; "Blast-Furnace Bears," by Dr. J. E. Stead; "Technical Aspects of the Establishment of the Heavy Steel Industry in India," by Dr. A. MacWilliam; "Production of Sound Steel by Lateral Compression of the Top Portion of the Ingot," by B. Talbot; "Steel Ingot Defects," by J. N. Kilby; "Notes on Inclusions in Steel and Ferrite lines," by Dr. J. E. Stead; "Non-Metallic Inclusions in Steel," by A. McCance; "A Cause of Brittleness in Mild-Steel Boiler Plates," by Dr. W. Rosenhain and D. Hanson; "Effect of Mass on Heat Treatment," by E. F. Law; "Effect of Cold Work on the Divorce of Pearlite," by J. H. Whiteley; "Effect of Cold Working on the Elastic Properties of Steel," by J. A. Van Den Broek; "Iron, Carbon, and Phosphorus," by Dr. J. E. Stead; "Damascene Steel," by Colonel N. Belaiew; "Protection of Iron with Paint against Atmospheric Corrosion," by Dr. J. N. Friend; "Determination of Cobalt and Nickel in Cobalt Steel," by W. R. Schoeller and A. R. Powell.

The Microscopic Examination of Brass and Bronze.*

By Ernest J. Davis.†

The examination of the internal structure of metals and alloys by means of the microscope is not a very old science. Probably the first publication was that of Widmanstätten in 1808. Widmanstätten polished and examined samples of meteorites, and obtained characteristic figures such as parallelograms and triangles. This structure is so characteristic that it is often known as

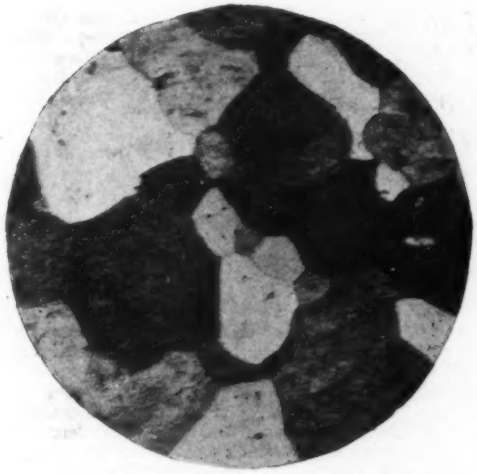


FIG. 1.—PURE COPPER, MAG. × 100 DIA.

"Widmanstätten structure," after its discoverer. This type of structure is generally found in steel and occasionally in non-ferrous alloys, and is usually a sign of weakness. It was not until 1864, however, when Dr. Sorby, of Sheffield, took up the study of iron and steel that any great strides were made. Dr. Sorby (often called the "Father of Metallography") published microphotographs in 1882-1887, which have never been surpassed. With Sorby might be mentioned Martens, who did similar work but quite independent of Sorby; but the extension of Sorby's work is largely due to Osmond, Stead, Arnold, and others. Most of these workers studied iron and steel, and only within the last few years have non-ferrous metals been studied microscopically.

The mechanical properties of alloys depend to such an extent on their physical structure that without a knowledge of the latter full advantage of the former cannot be taken. Many of the failures in the making of alloys are due to changes in the method of treatment or in other ways, and these failures cannot be prevented until the causes which produce them are known, and this knowledge can be obtained by microscopic study. The chemist and chemical analysis tell us faults of composition, but as to how the various components are mixed, or whether, say, a brass rod is of the Beta phase on the outside and normal Alpha+Beta in the centre matters little to him, nor does the cracking of the rod on cold rolling; such cases are for the metallographist to worry out. The application of the microscope to the study of the structure of metals and alloys has developed rapidly within the last few years Accurate methods of examination are known, and a vast amount of data has been gathered. In fact, practical metallography has now come to be regarded as a valuable aid to the chemist in a well-equipped works.

For the microscopic examination of metals and alloys, three things must be considered:—First, the preparation of the sample, then the instrument with which the examination is conducted, and lastly the method of examination.

Preparation of Sample.

The preparation of a specimen of metal for microscopic examination necessarily begins with the choice of the surface to be examined. This is a matter in which the personal knowledge of the worker comes into play to a very large extent, for the choice of the section must depend in every case upon the particular object to be attained, and upon the conditions of the case. Thus, where an investigator is studying the structures of a series of alloys with regard to their possible constitutions, he will in general examine the entire vertical cross section of his ingots in order to detect any lack of uniformity of composition. It is not possible to

FIG. 2.—5% PHOSPHOR TIN, MAG. × 100 DIA.

examine the whole of every ingot, and in the case of large ingots a number of sections are cut out and examined. More complex conditions affect the choice of specimen in worked samples, as the influences of mechanical treatment always produce differences of structure, according to the direction in which the section is cut relative to that in which the work has been applied.

* Read before the London Branch of the British Foundrymen's Association, February 9, 1918.
† Silver Medallist M.I.M.

Having decided where to take the section, a piece about ⅜ in. × ⅜ in. × ¼ in. is cut out by means of an ordinary hack-saw, or a piece may be broken off by a blow from a hammer, etc. Oxy-acetylene blow-pipe should not be used, as the temperature obtained by the metal even at some distance from the line of the blow-pipe is high enough to appreciably alter the structure, and possibly efface the very features which are being sought.

The next step is to prepare a flat surface. This is accomplished by rubbing on a dead-smooth file. Grinding wheels may be used, those of the slow revolution type being preferable, as the heating of the surface of the specimen when using fast revolving wheels is apt to cause faulty structures to be produced. Having filed a flat surface on the specimen, it is polished on emery paper of increasing fineness. The writer uses papers starting with No. 1, 0, 00 and 000, and finally finishing on a revolving disc on which is stretched "Selvyt," fine wash leather or livery cloth, fed with a powder known as "Diamantine." The specimen is then ready for the development of the structure. The above procedure is, of course, modified according to the metal which one is working. For instance, aluminium requires extreme care, and it is sometimes better to use a little light oil on the emery papers when polishing.

The next step is to develop the structure for examination by the microscope. There are a number of ways of doing this, but the most useful is etching. The specimen is immersed in some reagent which attacks different constituents at

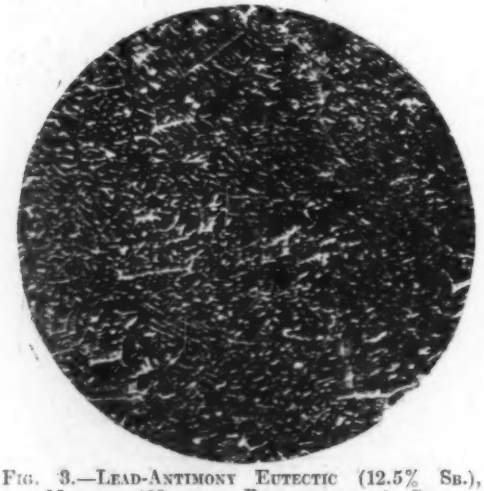


FIG. 3.—LEAD-ANTIMONY EUTECTIC (12.5% SB.), MAG. × 100 DIA.; REDUCED TO ¾ SIZE IN REPRODUCTION.

different rates, thus giving a means of identification under the microscope. Various reagents are employed for this purpose, but for non-ferrous metals dilute ammonia is a good all round reagent. Just a drop of the ammonia is carefully rubbed on the specimen with the finger until the required depth of etching is obtained, when the specimen is washed under the tap and quickly dried, and is then ready for examination.

A 10 per cent. solution of ammonium persulphate is also a good reagent, especially for alloys of Cu-Zn. Ferric chloride is useful for the Cu-Sn series, and a good formula follows:—FeCl, 10 grams.; HCl, 30 cc.; H_2O, 120 cc. This reagent may also be used for manganese bronze, certain aluminium alloys such as Al-Ni and alloys rich in Sb, Bi, and Sn. For white bearing alloys, 10 per cent. HCl is useful, but I have obtained very good results with 1 per cent. $H.NO_3$ in alcohol, for these alloys. For alloys rich in zinc or aluminium 5-10 per cent. caustic-soda is generally used.

The Microscope.

When the specimen is ready for miscroscopic examination, any good metallurgical microscope

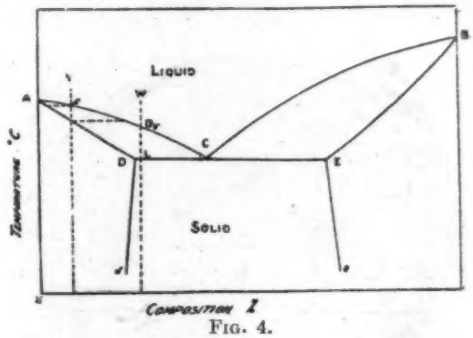


FIG. 4.

is suitable for the work; but it is desirable that it should be fitted with an inclining joint so that it may be used in both horizontal and vertical positions. It should have also a rough and a fine adjustment. Metallurgical microscopes are fitted with a stage upon which the specimen under observation may be moved backwards and forwards by mill-headed screws which enable one to examine the whole surface of the specimen.

Metallic specimens, being opaque, cannot be examined by transmitted light; consequently special illuminating apparatus has to be used. For the examination of metals and alloys vertical illumination is produced by having a hole in the tube of the microscope, just above the objective, and a right-angled prism placed in such a position that it reflects any light which passes on to it through the hole, down on to the specimen, and is then transmitted up the tube of the microscope past the back of the prism to the eye-piece Any good light will do for the illumination, but for photography a small arc-lamp is preferable.

The structure of metals and alloys, as seen under the microscope, may be divided into four distinct types, such as that of pure metals, chemical compounds, solid solutions, and eutectics. When a pure metal solidifies from fusion it is obvious that the resultant solid must be chemically homogeneous; it must have the same composition in all parts, and any lack of homogeneity can only be due to the formation of holes, by contraction during solidification, or perhaps from dissolved gas, if the term "pure metal" be not held to exclude metals holding gas in solution. As the metal solidifies crystallisation takes place, and the form and size of the crystals depend on the metal and on the rate of solidification. Very frequently crystals grow inwards from the cooling surface into the still molten interior, the main branches throwing out arms and the liquid mass subsequently freezing between them, thus forming a large feathery pattern commonly known as "dendritic."

More usually crystallisation commences from a number of centres, the crystals growing in all directions into the mother liquor, the spaces between them becoming gradually filled and finally pressing against one another, so that the regular crystalline form is destroyed and an irregular polygonal structure results. Fig. 1 is a good example of this type. As will be seen, there is a mass of roughly polygonal areas, separated from one another by narrow dark lines These polygonal areas are readily recognised as representing sectional views of a number of roughly polygonal

Fig. 5.—Alpha Solid Solution (Ni.-Ag.)

grains which constitute the entire mass of metal. The nature of these grains is now known and they are recognised as true crystals. It is true that these crystals lack one of the most striking features of many crystals, viz., geometrical outline, but this is explained by the fact that none of these crystals have had the opportunity for free growth, which is requisite for the development of geometric forms, the growth of individuals being stopped by their neighbours.

The essence of crystalline form does not reside in geometrical outline or shapes, but in the regular arrangements of the molecules within the mass, geometric outline being merely one result—a result which is only apparent in favourable circumstances. Why some crystals in Fig. 1 appear dark and others light is due to an optical effect, which can readily be proved by examining the same field under oblique illumination, when we get the reverse effect; those that appeared dark now appear light. In fact, by rotating the specimen on the stage of the microscope one can see the dark crystals gradually appear light and the light ones gradually becoming dark.

To understand the nature of this phenomena we must consider for a moment the manner in which the surface of the specimen has been prepared. The important point in the preparation is the etching process, since before etching the surface was practically a uniform plane. Now, the action of an etching reagent such, for example, as a dilute acid, is that of a weak solvent, and it effects solution by gradually unbuilding the structure of the metal exposed to its action. If the different crystals which have been sectioned by the polished surface are each built up on a separate system, each will be unbuilt by the etching fluid according to that system. This unbuilding process actually exposes a number of very minute facets, differing in size and position, but all of the same shape and similarly oriented, *i.e.*, all facing one way over the entire part of the surface belonging to one crystal, but, as a rule, differing from crystal to crystal.

Further, it is found that the etching fluid does not attack all the crystals at the same rate, in fact, the rate of attack varies from crystal to crystal according to the different orientation of the molecules of which the crystals are built up. An etched surface therefore consist of a series of polygonal areas corresponding to the various crystals sectioned, each at slightly different levels, and thus necessarily connected by short steeply-sloping surfaces, and each covered with a system of minute facets which are similar over each area but vary from area to area. Under vertical illumination the light, striking the steeply-sloped connecting surfaces, is totally reflected away from the microscope, and they appear to the eye as fine dark lines.

The minute facets are, if the etching has not been too deep, too minute to be seen except with very high powers, but the various systems of facets may be so arranged that some of them totally reflect the rays of light away from the microscope and appear dark, while others are more favourably arranged and reflect the light to the eye-piece and

Fig. 6.—Alpha Solid Solution (Cu.-Ni.).

thus appear light. If the etching process be carried far enough, the crystal facets can be seen and the mode of crystallisation of some of the metals has thus been demonstrated.

Chemical Compounds.

The next constituent—necessarily confined to alloys—is the chemical compound. None of these compounds are of much importance, with the exception of those that occur in bearing alloys, and, as a rule, inter-metallic compounds are hard and brittle and impart the same properties to alloys

containing them. On solidification these compounds behave exactly like a pure metal; in fact, we cannot tell by the microscope whether a substance consists only of a pure metal or wholly of a chemical compound.

Solid Solutions.

The term solid solution is given to a homogeneous mixture of two or more substances in the solid state. Its structure is exactly similar to that of a pure metal.

Eutectics.

The term eutectic means "easily melted," and is used to indicate that combination of two substances which has a lower melting point than any other proportion of the same constituents. Eutectic alloys, according to Dr. Stead, have usually one of three structures:—Curved plates, flat plates, and honeycombed or cellular. Fig. 3 gives a typical eutectic structure (an alloy of Pb and Sb, containing 12.5 per cent. of Sb, melting at 228 deg. C).

Most alloys are more complex in structure and contain two or more of the above constituents. In an alloy, as cooling goes on, one constituent—a solid solution—separates, and then the mother liquor solidifies, forming the eutectic, or there may be more than one stage of solidification before the eutectic point is reached.

To be able to predict the micro-structure of any particular known alloy it is necessary to have some knowledge of the equilibrium diagram of the series to which the alloy belongs. Fig. 4 is an equilibrium

FIG. 7.—ALPHA SOLID SOLUTION (CU.-SN.), DENDRITIC STRUCTURE.

diagram for the metals X and Z, and is one of the simplest forms of such diagrams. These diagrams are prepared by taking alloys of the metal X with increasing proportions of the metal Z, and determining the freezing points of each alloy; the freezing points are then plotted against the percentage composition, and a diagram as shown is obtained. The curve ACB is known as the "Liquidus," above which all alloys are liquid; the curve ADCEB is known as the "Solidus," below which all alloys are solid; and the line DE is known as the "Eutectic" line. To make the understanding of the diagram clearer, we will follow a few alloys from fusion. Take an alloy of composition Y and allow it to cool. Nothing happens until the liquidus ACB is crossed at the temperature of, say *c*, when crystals of the metal X begin to be deposited, and at the same time the mother liquor becomes richer in the metal Z. As the temperature falls more of crystals X are deposited, while the mother liquor becomes progressively richer in Z, until the solidus ADEB is crossed, when the remaining liquid solidifies as a whole, and microscopically we obtain a solid solution.

An alloy of this type, when examined under the microscope, often shows what is termed a "cored"

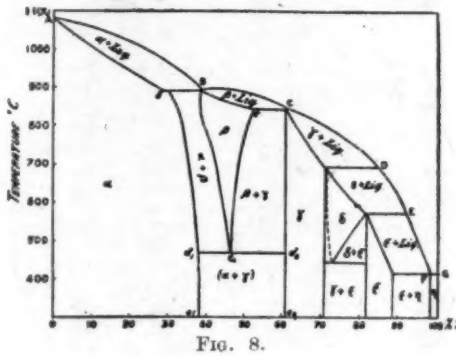


FIG. 8.

structure similar to Figs. 5, 6, and 7, the reasons of such a structure being that the crystals first deposited have the composition not of *c* but *d*, and those deposited last have the composition *e*, and as equilibrium can only be obtained by the process of diffusion, which is extremely slow in rigid solids, therefore it will be readily seen that if specially slow cooling is not resorted to, the interior of the crystals will have a different composition to the exterior, and the structure shown will be obtained. Now take an alloy of composition W, crystals of X commence to separate at D_1, and as the temperature falls the mother liquid becomes richer and richer, just as in the case of alloy Y, and finally solidifies at the temperature E, the mother liquid having by then obtained the composition of the eutectic. The microstructure consists of crystals of X surrounded by the eutectic XZ. An alloy of composition C solidifies at a constant temperature, and the structure consists, wholly of the eutectic. Alloys with compositions to the other side of the point C behave in exactly the same way, with the exception that crystals of the metal Z are first to separate on cooling.

Copper-Zinc Series.

We now pass on to consider the alloys of copper and zinc. Fig. 8 is a reproduction of the equilibrium diagram for these alloys, as worked out by Shepard, with the modification by Prof. Carpenter. The liquidus consists of six branches; there are no well-defined maximum points which would indicate the formation of chemical compounds, although claim has been made for them. The diagram shows in all six phases, but we shall confine ourselves to the first three, viz., those denoted by the letters α (alpha), β (beta), γ (gamma). The α phase, the first constituent that forms when zinc is added to copper, is a solid solution, and contains up to 37 per cent. of zinc, the position of the point *b* in

the diagram shows the limiting composition of alloys which in all circumstances contain only the α phase. The α phase of this series very often exhibits a cored structure which may be removed by annealing or mechanical work.

Most alpha solid solutions show a marked characteristic, namely, that of twinning. Fig. 9 shows the twinning of a 70 : 30 brass very well. This twinning is the swinging round as it were of a parallel band of the crystal, produced by mechanical work and annealing. Alloys containing from 30 to 37 per cent. zinc, show the existence of a new con-

FIG. 9.—TWINNING (70 : 30 BRASS). ARROW AT LEFT SIDE INDICATES TWINS.

stituent, viz., β beta. In cooling alloys in this range α separates out until a temperature of about 880 deg. C. is reached, when the remaining liquid solidifies, forming the β phase. Owing to the shape of the line b e these alloys pass from a region in which both α and β can exist side by side into a region where α only is stable, and where, therefore, β can only exist by rapid cooling. The α constituent is a comparatively soft and ductile body, which can easily be worked in the cold, while the β phase is much harder, stronger, much less ductile, and its presence in the alloy is at once felt by a decided decrease in ductility, increase in strength and hardness, and greater difficulty in cold working.

When the percentage of zinc exceeds 37 per cent. the β phase remains stable at all temperatures down to 470 deg. C., and slowly cooled alloys show a duplex structure containing both the α and β phases side by side. Rapid cooling affects the structure of these alloys by increasing the proportion of β stable at the ordinary temperatures. The effect of quenching is felt more near the alpha end, gradually decreases towards the middle of the range, and increases again towards the β end. Rapid cooling from a temperature above BC suppresses the β to α change, and may result in a homogeneous mass of beta.

A knowledge of the equilibrium diagram is very useful in determining the heat treatment of these alloys. The region of true stability of the beta phase is confined, according to Prof. Carpenter, to temperatures above 470 deg. C. At this temperature heat evolutions in the cooling curves occur, which Prof. Carpenter considers, in conjunction with his microscopical results, to indicate the decomposition of the β phase into alpha and gamma. This decomposition is extremely slow, and is not readily seen under the microscope, especially in pure Cu-Zn alloys. How far this decomposition of the β phase affects the mechanical properties of the alloys is not known, although it has been suggested as the cause of spontaneous cracking. It has already been mentioned that the beta phase is hard and brittle in the cold, but it easily lends itself to hot rolling or forging, while the alpha phase is considered unsuitable for hot working.

At the ordinary temperatures the alloys of composition between d_1 and c_1 appear to consist of α plus β, while those between c_1 and d_2 appear to consist of β plus γ. This latter phase is exceedingly hard and brittle, and its presence in alloys renders them useless for any purpose where strength and toughness are required. The usefulness of the Cu-Zn alloys for certain purposes is increased by the addition of small proportions of one or two other metals. The most important of those added elements are lead, tin, manganese, aluminium, iron and nickel; the so-called manganese bronze contains most of these elements. From the micrographic point of view, these added metals behave in much the same way, *i.e.*, the added metal is dissolved in one or the other of the constituents, probably the alpha solution up to a certain proportion. Above this limiting amount of the foreign metal a new constituent is formed, which usually is hard and brittle, so that a third metal in sufficient quantity has a deleterious effect.

The above elements are also capable of replacing zinc, that is they give a particular brass the appearance of containing more zinc than it really does. The zinc equivalents of the above elements have been worked out, and, according to Desch, are :—Aluminium, 6; Sn, 2; Mn, 0.5; Fe, 0.9; Pb, 1.0. From the analysis of the alloy and by a simple calculation from the above figures the apparent or fictitious zinc is found.

Bronze.

Bronze, as is well known, is an alloy of copper and tin. The diagram Fig. 11 is the equilibrium diagram for the Cu-Sn series, and is very much

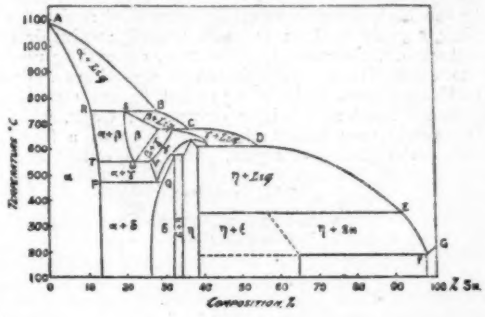


FIG. 10.

more complicated than that of the copper-zinc alloys and is still incomplete. As is usually the case, the most useful alloys occur at one end of the diagram; in this case alloys containing more than 20 per cent. of Sn are very little used. The first constituent to appear when tin is added to copper is alpha, and alloys up to 12 per cent. tin contain this alpha phase. The Cu-Sn and the Cu-Zn alphas are very much alike; in fact, all solid solutions are alike. When rapidly cooled the Cu-Sn alpha exhibits the dendritic structure characteristic of solid solutions which have not attained

equilibrium, but slow cooling, or subsequent annealing equalises the differences in composition which exist between the interior and exterior of the crystals and results in the uniform crystalline aggregate with which we are already familiar.

In alloys above 12 per cent. of tin, we find a new constituent appearing, viz., delta. The delta phase is hard and brittle, but is only stable up to about 500 deg. C., where it is transformed into the beta phase, which is much more reasonable in its mechanical properties. The alloys richer in tin, particularly covering the complex part of the diagram containing 20-40 per cent. of tin, although of great theoretical interest, are of little industrial use, and will not be discussed.

The alloys of copper and tin which have been put to practical use may be divided into several groups :—

Coinage Bronze contains 4 to 8 per cent. Sn, and includes the alloys used for the so-called copper money and medals. It is sufficiently hard and tough to resist considerable wear, and malleable enough to be stamped to shape. These alloys can be rolled, stamped and drawn, either hot or cold, their structure being that of the alpha solid solution and very often characteristic twins.

Gunmetal contains 8-12 per cent. Sn, and was the metal used for ordnance in the old days. Gunmetal is largely employed for mechanical purposes when strong castings are required. Zinc is sometimes added, and makes the alloy more fluid, gives sounder castings and somewhat softens the alloy. Lead has been used for the latter purpose, but it is not always a desirable constituent. The structures of gunmetals vary according to the tin content; the lowest members may consist of the single alpha phase; while those containing high percentages of tin will show on microscopic examination in addition to the alpha phase either beta or delta, according to the heat treatment.

Bearing Bronzes.—These bronzes contain from 12-16 per cent. of Sn, and very often from 2-4 per cent. of copper is replaced by zinc, and sometimes lead is included in the mixing. The appearance under the microscope of these alloys is very similar to the higher members of the gunmetal series, but they usually contain more of the alpha-plus-delta eutectoid*, the amount, of course, depending upon the composition. Phosphorus is sometimes added to these alloys, and when present in any quantity forms a hard and brittle compound, Cu_3P, which is usually seen under the microscope as a fringe round the grains of alpha, plus delta eutectoid.

Discussion.

Mr. W. Ellis said he took it that the Paper dealt with pure metals, but in practice they did not always have pure metal to use, and if someone like Mr. Davis would deal with the metals met with more often than not, it would be even more interesting. The Paper indicated what ought to be, but it was seldom obtained.

Mr. Lambert, after congratulating the author upon the value of his Paper, expressed the opinion that he might, with advantage, have made clearer the uses of the microscope. The photographs showed, for instance, the copper-zinc series of alloys, and one of them was called an "alpha solid solution." That was a Greek term, and he had no doubt that some of the diagrams appeared Greek to many of them. The value of the microscope was to determine the structure of the alloy. In practice they took a specimen and polished it, and it seemed free from porosities. The tensile test was, say, 24 tons. They made what they believed was a similar alloy, but on that occasion, perhaps, the fireman had not lost as much spelter in making the alloy, and the test bar gave perhaps 31 tons. They tried to do it again, and dropped to 24 tons, and perhaps the next time it was 28 tons. These were figures that occurred in everyday work. What was the reason? As far as they knew, their pot mixings were the same. The chemical analysis would show there was more spelter, but the microscope showed the reason why the tensile strength varied. The proportion of white constituent to dark constituent determined very largely the tenacity of the alloy. The arrangement of the white constituent and the dark constituent also had a very considerable influence on the result of the tests. One of the strongest alloys, as indicated in the photographs, might be accompanied by a certain amount of brittleness, whereas another day a similar alloy would have a considerable amount of ductility. Examination by the aid of the microscope enabled tests to be obtained within half a ton. The great virtue of the microscope was that it determined to a very large extent wherein the casting alloys were at fault. Many foundrymen were under the impression that industrial alloys were homogeneous compounds. The majority of the working alloys were heterogeneous. The microscope showed contractions of the various constituents in various directions, leaving spaces between them. He had been struck very much by the fact that although classes were held in London for the micro-examination of metals, it was very rarely that a foundryman went to them, yet the microscope was a most essential thing to a foundryman. The microscope was the finest detective, and he advised all who were really interested in foundry work to take up the study of the microscope and the micro-examination of metals.

Mr. Davis said that porosity applied more to the copper-tin than to the other series.

Mr. Lambert said it applied to alloys which were generally put under pressure, such as the gunmetals and copper-tin bronzes generally.

The Secretary (Mr. J. Gaunt) said that it would be very useful if the author would give the results of an investigation of some bad samples. If they could be shown the means of determining why a sample was bad, it would be of great service. He had had a great deal of experience of gunmetal work, especially in connection with porosity, and in almost every case he found in the micro-photographs, with 120 magnifications, certain areas which were centred round black dots. He, as a practical man and not a scientific man, had put that down to oxide in the metal, but he did not know whether he was right in doing so. With regard to the preparation of the specimen, the author said that could be done by a hacksaw, or a blow from a hammer, and that he did not recommend the oxy-acetylene method of cutting a portion out of the sample. A blow from a hammer, however was hardly the best start for an investigation on micrographic work. He was rather interested in knowing what was the best lamp. At the present time he was using an incandescent gas-burner, but he noticed when in the North that the "Pointolite" electric lamp gavé good results. What condenser did the author use between the source of light and the microscope? Whilst microphoto-

* Modified term of eutectic; results from a decomposition of a solid solution.

graphic work was useful in solving troubles that existed, what foundryman wanted was something which would enable them to prevent the troubles occurring before the metal was put into castings. In this connection he was beginning to think that pyrometry would play an important part, and that there was a great deal more in temperature control than in anything else. He would be dealing with that matter at the next meeting. He agreed that foundrymen should support classes more than they did, but to a certain extent he did not blame the foundrymen. There were certainly classes for micrographic work in London, but he did not think the Education Authorities secured the right type of man to run the classes. These men were undoubtedly well educated, but in many cases they were not connected with practical work, and that was one of the reasons why the practical foundryman fought shy of these classes. His experience of one teacher in London was that he could certainly tell the students what the microscope was, and he could indicate the constituents, but he could not go much farther. He once sent him a specimen of cast iron which had a tensile strength of 26 tons, and it quite took his breath away when the teacher in question said it was very weak. It made him hesitate to put himself in the hands of men like that.

Mr. J. Stone asked what was the reason for slow polishing. One could fast polish steel and iron and see through the microscope the same structure as was obtained when slow polishing was adopted.

Mr. Davis said that when using soft metals in which the hard constituents were bedded in the soft matrix a fast polishing method would in all probability tear out the hard constituent and leave nothing but the matrix of soft material and holes. There would not be any structure at all. Even with steel, with a fast revolving emery wheel, unless great care were exercised, a totally different structure would be obtained. He preferred polishing everything by hand, because non-ferrous metals were very difficult to polish, especially copper and aluminium. Replying to Mr. Gaunt on the question of black dots, they were probably holes where the hard constituent had been drawn out in polishing, or sucked out, as it were, in cooling off the casting. The last to solidify in these alloys was the alpha and delta entectoid, and the weight of the casting, if it were cooled slowly, squeezed some of it out. The outside then looked "tinny," and that was why, unless great care was taken with the casting, some of these alloys did not stand pressure very well. He was afraid Mr. Gaunt had rather misunderstood him on the question of the hammering of the specimen. He was thinking of taking a sample from a mass of metal, and a piece could be hammered off.

Mr. Barrett thought this would crush the crystals.

Mr. Davis replied that there would be an irregular surface, which would have to be filed down below the point—if there was such an effect—of crushing the crystals, but with a soft metal hammering could not be adopted. With regard to the lamp, he used a small arc lamp, taking 4 amperes. It was known as the "Lilliput" arc lamp.

Mr. J. E. Hurst said he believed the Pointolite lamp was made in London. It was a very good lamp, and he could recommend it. It started with a big current through a variable resistance, and continued to burn with a small current. The lamp was made by the Ediswan Company. He had had one in use for about 18 months—a single bulb—and it was still as good as ever. Referring to the equilibrium diagram shown by the author, could any reason be given why in the series of alloys on the left-hand side the constituent X was first to be deposited in preference to the constituent Z? He had often asked that question, but had never got a satisfactory answer.

Mr. Davis said the only reason he could see why the constituent X was first deposited was because it was the predominating metal in the solution.

Mr. Gaunt, referring more particularly to aluminium alloys and oxidation, said he had found that if the metal was left to sweat in the furnace and was unfluxed, the black points he had referred to always occurred. They showed within the alpha constituent. He knew they were not holes, but what they were he did not know.

Mr. Davis said it was possible they were oxide patches. In polishing aluminium alloys, however, it was the luckiest thing under the sun to get the surface free from holes. Answering Mr. Gaunt, with regard to the condenser, he said an ordinary condenser and lens would do, but with an incandescent gas light it was well to have a sheet of ground glass between the lens and the condenser. In his own apparatus he used a German lens and condenser in one for ensuring a parallel beam.

Mr. Lambert, speaking with regard to being able to avoid mistakes by the use of the microscope, mentioned that there were many instances in which a sample of non-ferrous metal was taken from the pot or furnace and examined microscopically before the casting was made.

Mr. Barrett asked what area was recommended for the specimen, or was that entirely governed by the apparatus used? The author had mentioned a weak solution of ammonia to be rubbed on the specimen with the finger. He imagined it would be rather dangerous to use the finger in some of the etching reagents mentioned in the Paper. Would not the temperature of the finger produce a difference in the result to what would be expected if the etching reagent was used in some other manner?

Mr. Davis said the size of the specimen depended upon what was being investigated. If the specimen was to be polished and a record of it taken photographically it was best to have it as small as could be held conveniently in the thumb and forefinger, about $\frac{3}{4}$ in. sq., and $\frac{1}{4}$ in. thick. If a 2-in. rod was being examined it might be necessary to polish the whole area. As to rubbing ammonia on with the finger, he had found that quite satisfactory, and gave the same result as placing the specimen in a 10 per cent. of ammonia per-sulphate, but sometimes one and sometimes the other was best. The latter left the specimen a little yellower. He had tried at times all the reagents he knew, and in one case a solution of chromic acid gave very satisfactory results with alloys of Pb-Sn. If one acid failed, it was better to repolish and etch again. The use of the finger did not raise the temperature very much, especially if the specimen were washed in cold water.

Mr. Stone asked if the difference between bronze, cast iron or steel could be told from an inspection of photographs under the microscope.

Mr. Davis said there was a great deal of difference between the structures of these three, and anybody with any experience of the microscope could differentiate between them.

Mr. Richardson thought it would be a useful thing if the magnifications could be standardised. At present lecturers varied, and the different mag-

nifications of presumably the same thing gave different structures.

MR. DAVIS said the standardisation of magnifications had already been suggested by the Institute of Metals, and 100 was recommended for ordinary examinations. If they were looking for special features there must be different magnifications. In his case the micro-photographs were 100 magnifications.

MR. LAMBERT referred to the polishing of steel on an emery wheel at high speed. A 0.35 carbon steel gave an absolutely different structure prepared in this way to what it did when prepared by hand on a slowly revolving wheel. In one case, after a specimen was polished and etched, there were spots on the specimen. He wanted to have the surface removed, and handed the specimen to the grinder. When it was re-etched there were long, narrow, parallel bands on the surface which it was found difficult to etch. At the time he did not know that it was due to the grindstone, but he found out subsequently that the difficulty was due to a dirty wheel, and he wished to give a word of warning on this point. In order to get the best result, he advised running the polishing lines in one direction, to reverse them and bring them in the other direction. By doing this and using different grades of paper the specimen could be polished with the greatest ease in the shortest time.

The CHAIRMAN said that foundrymen wanted some method of examination of their castings which they could work upon, say, within an hour. The method of preparing a sample for micro-photographic treatment could not be done in an hour.

MR. J. GAUNT proposed a vote of thanks to the author, which was seconded by Mr. Stone, and carried with acclamation.

MR. DAVIS, replying, said that he was able to take a sample from the furnace, carry it to the laboratory, cool it under standard conditions, polish it, etch it, examine it under the microscope, calculate from the structure the amount of zinc added, take that figure back to the foundry, and tell the foundryman how much zinc to add, all in ten minutes.

The Electric Furnace in the Foundry.

Mr. Edwin L. Crosby, who is affiliated with the Detroit Edison Company, read a Paper at the recent Boston Convention of the American Foundrymen's Association, under the title "The Electric Furnace from the Central Station Viewpoint," in the course of which he stated that up to the present time about 200 electric furnaces of various types, and having an annual capacity of 1,200,000 tons of steel, have been installed or contracted for in North America. This steel output involves the use of about 750,000,000 kw.-hrs. Many concerns, both in the steel foundry trade and in central station supplies, have made serious errors. Many steelmakers and foundrymen have installed electric furnaces which, for one reason or another, were utterly unsuitable for their use. Also many central station men have been misled by furnace salesmen. Errors in installation and application should be avoided through a closer study of electric furnace equipment and service than has been made in the past. The power salesman should have a fairly good understanding of the metallurgical practice involved before attempting to give advice or data. With the possible exception of one type of arc furnace, and the certain exception of the induction furnace, all steel furnaces on the market to-day, if properly installed, will operate with a power factor of 80 to 85 per cent. during the early stage of the melting period, later rising to 85 to 90 per cent., and finally to a point as high as 95 per cent. or better during the refining period. Regulation, phase balance and wave distortion have not received sufficient attention. Present electrode regulation is at its best very unsatisfactory, it being impossible with any existing equipment to obtain sensitive regulation without considerable hunting of electrodes and disturbance of phase balance. Very careful consideration should be given to this point, and it may be advisable to place in the furnace circuit carefully selected reactances. Recent oscillographic investigations have shown a very marked distortion of the current wave in all types of arc furnaces. This is a very important subject, as it may affect the accuracy of induction type watt-hour meters. Large wave-distortion is also detrimental to the operation of other apparatus connected with the system; it will, for instance, lower the efficiency of rotary converters.

The representative of a central station anticipating an electric furnace load, said Mr. Crosby, should make himself thoroughly familiar not only with the working of various types of furnaces, but also with his future customers' requirements. As stated in the report of the Electric Steel Furnace Committee of the National Electric Light Association last year (1917), that body expressed the opinion that the electric furnace should supplant or successfully compete with both the crucible and the converter for any purpose. Given usual freight differences, it should be able to supply local markets with the equivalent of the higher grade open-hearth material, local scrap markets being favourable. Under normal conditions, however, the committee did not feel that the electric furnace was a competitor in tonnage steel. In the steel foundry trade there appears to be no reason why the electric furnace, when thoroughly developed, should not supplant practically all other methods in foundry use. By close co-operation between foundrymen and the central station such a development can quickly be realised. As a representative of a competitor of the electric furnace once remarked, "The electric furnace method is the ideal method for making ideal steel."

LARGE ELECTRIC STEEL FURNACES IN AMERICA.—One of the largest electric steel plants in the world is now in operation at the South Works of the Illinois Steel Company, South Chicago, Ill. One of the two 25-ton Héroult furnaces started on November 9 with the other following at once. It has been decided to instal a third 25-ton furnace in this plant immediately. The two 15-ton furnaces there have been at work for some time.

IMPROVED LADLE FOR STEEL FOUNDRIES.—Mr. James C. Davis, one of the vice-presidents of the American Steel Foundries in Chicago, has designed a new type of "self-skimming" ladle for steel foundries. For a given capacity he proposes to increase the usual height of the ladle and to reduce the mean diameter accordingly. The object of this is to reduce the area of contact between the molten steel and the slag by about 45 per cent., as the steel is prone to exchange part of its silicon for the phosphorus in the slag, resulting in porous castings. The greater height increases, moreover, the ferro-static pressure at the bottom, and thus—the inventor contends—helps the slag to rise to the top. Near the top of the ladle several circular holes are provided, at different levels and placed along a spiral line, for the purpose of draining away the slag, while the ladle remains upright, until the depth of the slag is reduced to a mere "blanket" for preventing the chilling of the molten steel. The holes are plugged in the usual way with a mixture consisting mainly of silicious sand with clay for a binder. The ladle, which consists of a brick-lined outer sheet-metal shell is arranged for bottom-pouring, the hole being closed with a "stopper" reaching to the top of the ladle.

Electric Carbon Tool Steel.

By John A. Holden.

War conditions have stimulated British manufacturers to adopt the electric process on a large scale. The enormous demand for tool and alloy steels, together with the difficulty in obtaining adequate supplies of Swedish iron, made the inception of the electric furnace a necessity. In this country the arc furnace is favoured, and although there are many designs of such furnaces, this article will deal with the Héroult type, because it is the one with which the author has had experience. For the production of carbon tool steel this electric furnace is particularly suitable. Cheap raw material, consisting of ordinary-carbon turnings, stamping trimmings, etc., can be refined and converted into tool steel of the first quality. The cost of production is low, being less than one half of the cost of making crucible steel. The charge is under direct control throughout; the purity of the product is unquestionable; the composition required is assured, for it is determined only by the accuracy of the bath sample analysis.

In order to obtain the necessary purity the furnace is lined with a basic hearth. Burnt dolomite, crushed and mixed with hot tar and rammed hard, gives a very serviceable bottom. The walls up to and two courses above the slag line are built of magnesite bricks; above this silica bricks are used throughout. In fine the furnace is lined in a manner similar to the basic open-hearth furnace. The capacity varies between 10 cwts. and 10 tons; the 3-ton is a very useful size for making carbon tool steels, and it will be convenient to describe the working of a furnace of this capacity.

The working differs materially from all other processes. The operations can be divided into two distinct sections:—(1) Oxidation of nearly all the carbon, manganese, silicon, and phosphorus. (2) Reduction of the sulphur and of the oxides left in the metal from the preceding operation. It may appear paradoxical to remove the carbon at one stage, and add it at a later stage, but it must be remembered that to oxidise the phosphorus to about 0.01 per cent. the carbon must be reduced to at least 0.10 per cent.

The furnace being hot from a previous cast, the melter examines it to determine the amount of fettling required. Usually the slag line only requires attention. The lime is charged on the furnace bottom, followed by the iron ore, and in turn by a substantial layer of turnings. The slag line is then fettled with burnt dolomite, crushed to pass through a ¼-in. sieve. If crop ends, or casting heads, etc., form a portion of the charge, they are thrown on to the bed of turnings. After this a further charge of turnings is added. In order to protect the lining the scrap is charged high round the walls, no harm being done if it reaches the roof. To facilitate melting the scrap should be lower in the middle of the furnace.

The current is put on, and by operating the electrodes by hand a steady load is soon obtained. The time for melting is determined by:—(*a*) Size of the charge; (*b*) current supply; (*c*) condition of the furnace lining; (*d*) character of the scrap; (*e*) skill of the furnacemen. Below is given the complete history of a typical heat made in a 3-ton Héroult furnace operating on a 3-phase current of 4,500 amps. on each phase, at 90 volts. The lining was in good condition, and the furnace was operated by skilled men.

If the scrap is light it will not be possible to get the whole charge in the furnace at first. In this case the remainder is added as soon as there is room for it. If the available scrap is very light it is found economical to crush it either in a pug mill or in a stone breaker. From time to time the melter examines his slag. If it assumes a brownish colour more iron ore is added. During the period of melting the slag is maintained very fluid, and contains an excess of oxide of iron. As soon as the charge is hot enough, and sufficiently oxidised, the scrap clinging round the banks is carefully pulled into the bath. After a short interval the electrodes are run up high above the level of the metal; the current is switched off, and the furnace tilted to pour off slag, care being taken that no metal is teemed. The bulk of the slag having been poured, the remainder is skimmed off with rakes. If the metal is well oxidised there will be no boil on the surface, and brown fumes will be seen to escape through the electrode holes in the roof. It is important that the bath should be well skimmed, particularly when the steel is to be recarburised. When skimmed the furnace is tilted back to the horizontal position and recarburised to the calculated degree. For recarburising anthracite "breaker duff" gives consistent results. It dissolves rapidly, and can be relied upon to give about 55 per cent. efficiency.

After recarburising, ferro-silicon is added in the proportion of 1 lb. of 50 per cent. ferro-silicon for every 2 cwts. of steel charged. Fluorspar and lime are then added to form a slag, and the current switched on. For finishing off a lower pressure is employed, usually about 70 volts. As soon as the steel is hot enough to pour well, a sample is taken for carbon analysis. Whilst this is estimated the steel is deoxidised, and simultaneously the slag is put into the right condition. The deoxidation of the metal is effected by means of ferro-silicon; the deoxidation of the slag is effected by anthracite, or ferro-silicon dust, or both; the electrodes in a measure also deoxidise the slag; the carbon reduces the oxides with the formation of carbon monoxide.

A good finishing slag is either cream or white in colour, porous and viscous in appearance. At first the slag is brown and mobile; with cautious additions of anthracite and ferro-silicon dust a satisfactory slag is obtained. Care is taken not to add an excess of anthracite, or a grey slag loaded with calcium carbide will be obtained, resulting in erratic carbon percentages in the steel.

From time to time samples of the steel are taken and poured into a small mould; the first two or three are "wild." An addition of ferro-silicon is made after each (equivalent to a theoretical 0.06 per cent. Si) until one is obtained which solidifies without rising. The steel, of course, is given time for each addition to react with the

dissolved oxides. To obtain a "dead" melted steel and a "white" slag occupies about 35 minutes from the time of recarburising. Steel made in either the basic arc or induction furnace has a well-known peculiarity: it cannot be cast into sound ingots unless the silicon content is at least 0.10 per cent. The silicon is often a stumbling block to the novice. However, with experience it is possible to judge the silicon percentage nearly as accurately as a chemist can estimate it.

During the whole time of deoxidising the temperature of the bath is carefully watched, the heat being controlled by adjusting the amperage on each phase. As soon as the steel is dead melted, and the slag is in good condition, the final additions are made. Ferro-manganese or spiegel is added to give the required manganese, and if the carbon is not high enough an addition of pig-iron is made. In a correctly finished steel these additions will yield 100 per cent. efficiency.

Details of a Carbon Tool Steel Heat made in a 3-Ton Héroult Furnace.

8.35 a.m.—Commenced charging.

9.0 a.m.—Current switched on. The furnace contained 3 tons 5 cwts. of scrap, 1½ cwts. of lime, and 1 cwt. of iron ore.

10.30 a.m.—Remainder of the scrap (10 cwts.) added.

11.20 a.m.—½ cwt. of iron ore added.

11.40 a.m.—Sample taken, hammered and quenched from about 900 deg. C. Bending test proved that the metal contained very little carbon.

11.50 a.m.—Banks cleaned.

12.0 p.m.—Furnace tilted to remove the oxidising slag.

12.10 p.m.—Bath recarburised with 125 lbs. of anthracite, 37 lbs. of 50 per cent. ferro-silicon added, followed by 1 cwt. of lime and 35 lbs. of fluorspar.

12.25 p.m.—Sample taken for carbon estimation.

12.26 p.m.—Sample poured. Steel very wild; 10 lbs. of lump ferro-silicon and 10 lbs. of anthracite added.

12.34 p.m.—28 lbs. of lime and 5 lbs. of dust ferro-silicon added.

12.39 p.m.—Steel almost dead melted: slag light brown in colour. 5 lbs. of anthracite and 5 lbs. of ferro-silicon added.

12.46 p.m.—Steel dead melted—silicon about 0.12 per cent.; slag white and frothy. Final additions made. (Spiegel 100 lbs., pig 78 lbs., 50 per cent. ferro-silicon 10 lbs.)

12.55 p.m.—Steel cast.

Total charge, 3 tons 15 cwts.

Total anthracite, 140 lbs.

Total ferro-silicon, 67 lbs.

Steel in the ladle, 3 tons 10 cwts.

Duration of the heat, 3 hours 55 minutes.

Current used, 2,205 kw.

Kilowatts per ton in the ladle, 630.

Maximum demand on the power station, 650 kw. per hour.

Analytical Data.—Bath when the first slag was removed: C, 0.07 per cent.; Mn, 0.08 per cent.; S, 0.043 per cent.; P, 0.007 per cent.

Bath at 12.25 p.m.: C, 0.90 per cent.

Steel when cast: C, 0.99 per cent.; Mn, 0.35 per cent.; Si, 0.18 per cent.; S, 0.018 per cent.; P, 0.007 per cent.

Specification: C, 0.98/1.03 per cent.; Mn, 0.3/0.4 per cent.; Si, 0.15/0.20 per cent.; S and P, 0.025 per cent. max.

First slag: SiO_2=7.80 per cent.; FeO=39.30 per cent.; CaO=38.80 per cent.; P_2O_5=0.85 per cent. Second slag: SiO_2=23.85 per cent.; FeO=trace; CaO=68.80 per cent.

Electric-Furnace Progress.

The following notes on electric furnaces have been forwarded by Messrs. T. H. Watson and Co. (of Sheffield), Ltd.:—

In Canada there are now 54 furnaces running, with a capacity of 173,000 tons of iron and steel, 50,000 tons of ferro-silicon, and 8,000 tons of ferro-alloys per annum. The production of steel in electric furnaces was 30,960 tons, as against 19,639 tons in 1916.

In England we are only just realising the immense possibilities of the electric furnace for steel and castings. The need of very high-grade alloy steels for aircraft has given a great impetus to the electric-furnace industry here. Some of these intricate alloy steels can only be successfully made in the electric furnace, but it is not yet realised that all steels except the cheaper basic qualities can with advantage be treated electrically, either complete by melting or by refining hot metal only. The increasing shortage of hematite pig-iron will undoubtedly give the electric furnace a fair opportunity of proving what it is capable of, and it is to be hoped will remove some of the fears and scruples that in the past have prevented its being more widely adopted. The attitude of many of the authorites in the past has been to find sufficient reasons for preventing electric furnaces being installed, instead of the commonsense reasons why they should be. All progress is met with the same inertia, but regard should be paid to what is being done in other countries, particularly America and Canada, if the British steel trade is not to be placed in a very unenviable position for competing in foreign markets after the war.

One plant in the States has under installation a number of furnaces of 15 and 25 tons capacity, the output of which will more than equal our total pre-war electric-steel production. Five years ago there were only 19 furnaces in the States and three in Canada; to-day the figures are 233 and 54 respectively. The American Navy Department has adopted an English type of furnace — the "Greaves-Etchells"—and a number of 6-ton units are being built for the Navy Yards. The same furnace has also been adopted by Dr. J. A. Matthews, of the Halcomb Steel Company, and by the American Radiator Company.

New electric furnaces have successfully been started up at the Leyland Motor Works, Leyland, and at Messrs. Stewarts and Lloyds, Limited, Glasgow. The type in each case was the 3-ton "Greaves-Etchells" furnace. They will both run on high-grade steel castings.

The shortage of pig-iron opens up a very wide field for melting turnings and scrap by the electric furnace, and it is safe to say that any concern with an excess of such scrap and which buys castings could with advantage install electric furnaces. The whole of the charge can be made up of such material, and the finished product is undoubtedly superior to ordinary steel castings.

Use of Iron Moulds.

At a meeting of the Birmingham Branch of the British Foundrymen's Association on January 26, Mr. J. Shaw (President of the Branch) in the chair, a Paper was read by Mr. M. Riddell (President of the Scottish Branch) on "Some Observations from the Use of Iron Moulds." The following are abstracts of the speaker's remarks:—

The demand for certain forms of iron castings for munitions to be made in permanent moulds was the means of bringing many ironfounders face to face with problems of which they had never thought and with difficulties which they had never contemplated. It was the writer's privilege to come into contact with several of these founders who were tackling the question, and, consequently, some of the observations to be made will be of a general nature based on that experience.

The first observation is that there is great lack of knowledge among ironfounders concerning the physical phenomena of cast iron, and a consequent absence of the scientific control in the foundry which such knowledge would give.

The foundry trade is roughly divided into two sections, of which heavy or jobbing shops form one and those engaged in making light castings the other. In the former, one finds that the iron mixtures used are generally made up according to chemical analyses, and to this extent we may say there is some attempt in these shops to adopt scientific control. In the other section, to which the writer belongs, pig-irons are judged almost solely by their prices, and the chemical analyses are rarely considered.

The spirit of commercialism which prevails in both sections is probably responsible as much as anything else for this backwardness. By its failure or reluctance to take the long views which science demands, and its desire for speedier returns than technical research will offer, progress is really hindered. Before the days of the war the question was frequently asked, what was the use of troubling about the science involved in cast iron so long as business could be carried on without it? The necessity of meeting the many and varied specifications of castings for war purposes has brought about a change of view to a great many, who have come to realise that the spirit of commercialism, by excluding other essentials in the foundry, may sometimes defeat its own ends. A splendid opportunity is thereby offered to the British Foundrymen's Association to come to the rescue by making its claims and objects better known among foundrymen. It is a duty which every member owes to himself, to his neighbour, and, above all, to his country, if it is to maintain the supremacy that everyone desires; to convince his fellow founders that the progress of the industry on scientific lines can best be accomplished by such co-operation of all those interested as this Association affords.

Another general observation is, that too much prominence has been given to the function of the chemist in the foundries, as well as in those quarters from which specifications are issued. There is a somewhat prevalent belief that the solution of all problems connected with cast iron is to be found alone in chemical analysis. This view, of course, is far from being correct, for, as Dr. Rosenhain said in a lecture before the Sheffield Branch in April, 1915—"the things that matter most to metal happen when the metal is cooling, and, in order to avoid pitfalls, accurate knowledge of what it is that takes place during the cooling process is necessary." There is no doubt that while a good and accurate chemist is a most valuable and necessary adjunct to any foundry that is to be worked on scientific lines, as a chemist his sphere is limited, and that what happens to the iron from the time it enters the cupola is outside his knowledge and control. This is well illustrated in the tests reported in Mr. Hailstone's Paper on "Liquid Contraction in Cast Iron," wherein he shows a wide variation in physical results from a series of bars cast from the same metal.

The critical time for iron is after it has entered the control of the foundry manager or foreman; and its character and suitability are determined, not by the chemical analysis of the iron used, but by the treatment to which it is subjected in the foundry. The fact that so much importance attaches to the physical changes in iron makes it incumbent on the foundry manager to acquire a knowledge of the conditions which regulate these changes, or, in other words, to learn the physical science of cast iron. The road to this knowledge is not easy, as the subject is a big one and will demand much study and observation. Difficulties and disappointments will have to be encountered, and these, when properly faced, will prove to be the best text books.

At the time inquiries were being issued for the castings which brought the permanent mould into prominence, a sample was exhibited and an analysis furnished, but without mention of the process of manufacture. It was not difficult, however, for anyone who understood the meaning of an analysis to see that the odinary methods of sand casting would not meet the requirements. The writer counselled his friends to ignore the chemical analysis offered, and tried to treat the matter as a problem involving physical principles first of all. It was necessary to consider to what extent these principles could be controlled in order to attain the desired end, and for that purpose it was decided to experiment with iron moulds. As it turned out subsequently, the use of permanent moulds was stipulated, and it was not long before several founders found themselves up against difficulties, in spite of the fact that an analysis of a suitable iron was furnished as a guide. He found considerable difficulty, in face of the prominence given to the analysis and also of a further recommendation from a source which claimed to have had much experience with permanent moulds, that it was necessary to use an iron containing not more than a certain quantity of combined carbon, to convince his friends that they were on the wrong track for a solution. It seemed rather strange to him that of all the substances which go to make up cast iron the combined carbon should be given such prominence as the determining factor, considering that the percentage of that constituent varies in different pigs from the same cast and at different ends of the same pig according to the rate of cooling; that it completely disappears as a distinct component in the molten metal, and that the percentage in the pig can give no indication of how much will appear in the casting. Except for the information it may give as to the melting qualities of the pig-iron, it would be much better

if combined carbon were excluded from analyses of mixtures altogether. Even in the examination made to ascertain the physical condition of a casting, a knowledge of the amount of combined carbon will give very little, and it may be even misleading unless at the same time the examiner knows in what particular form it is combined, whether in solid solution or as free carbide, and also how distributed in the casting. This last stipulation is particularly applicable to castings made in iron moulds, because it is frequently found that while the analyses revealed a very low percentage of combined carbon that carbon is concentrated in a very thin skin with a very high percentage of carbon, and which renders the casting unmachinable. These and similar recommendations, while admittedly issued with the best intentions, proved otherwise than a help to many of those who were impressed by their sources.

The pouring of molten metal into an iron mould has naturally the effect of hastening the rate of solidification. The very fine grain generally found in castings so made, is due to this effect, and not, as has been asserted, to liquid pressure on the mould during freezing. If there was such pressure while the metal was liquid or even plastic, it would get release and adjust itself according to natural laws. The best evidence that pressure is not responsible for the fine grain will be got from examination of a sand casting where the inside which has frozen under pressure from the solid and contracting outside, has a coarser grain than the outside which solidified under practically no such pressure. It is also noteworthy in this connection that the larger the section of the casting the coarser is the inside grain, notwithstanding the greater pressure exerted. The view which the writer holds is that the actual size of the grain is determined by the initial temperature of the molten metal and the rate of freezing. There is some relationship between the size of what might be called liquid grains and the temperature. At the vapour point these liquid grains are of infinitesimal proportions, but, as the temperature falls they gradually absorb and assimilate each other; just as we know happens to grains in the solid state under favourable conditions. The absorption takes time, and the extent to which it is carried will depend on the rate of cooling. Quick cooling from a high temperature produces finer grains while with very slow cooling are obtained large-sized and coarser grains in the casting. The condition of the grains found in meteorites is a good illustration of the operation of this law.

The cooling effect of the iron mould continues after the metal becomes solid, and it is here that the complications and difficulties are introduced. Unless the casting is of a somewhat heavy section, it may be cooled, either in whole or in part, too rapidly to permit of the changes which are necessary before all the carbon can separate out from the solid solution. When this happens it will be found that the parts of the casting so affected are excessively hard or chilled, and that it will be most difficult, and in some cases impossible, to remove the chill or hardness by ordinary processes of softening cast iron.

To ensure that a casting shall have its maximum softness, it is essential that the cooling down to below the pearlite change point should be as prolonged as possible. The problem presented, therefore, by the iron mould consists in devising means for counteracting the rapid abstraction of heat which it makes on the casting, and retarding the rate of cooling through the critical range. To accomplish the first the moulds had to be so constructed that the castings could be removed from the mould as soon as they were set. For the second a number of pots lined with fireclay and heated previously to the cast were distributed near the moulds. The castings were immediately transferred to the pots, buried in a mixture of sawdust and floor sand, and allowed to cool down. By this method the castings were able to retain some heat at the end of from 36 to 48 hours. Any casting which had got cooled down to a dull red before it could be put into a pot was thrown aside as a waster. That the method was effective was proved by analyses made at various times showing mere traces of combined carbon and also by reports received from the machine tests.

The most serious difficulty to be overcome in the case of iron moulds is the elimination of air holes and hard spots. One, and probably the most prolific, cause of air holes in castings arises from a source which is not generally recognised by foundrymen—at least it is never mentioned in discussions on that subject—namely, the aeration of the metal in the act of pouring. If one observes what happens when a stream of water from a tap falls into a basin containing water, he will notice that a considerable amount of air bubbles are produced, and also that they are carried well below the surface of the water. The example of an aspiratot for a small water-gas plant illustrates how this phenomenon is taken advantage of in

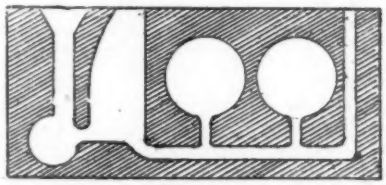


Fig. 1.

order to introduce air into the apparatus. The same action will take place when iron is being poured into the gate of a mould. To meet this in the case of a non-porous permanent mould an air trap between the gate and the casting has to be introduced. It is essential to make the trap of ample dimensions because the rapid cooling effect of the mould quickly forms a skin of rather viscous metal through which the air cannot escape. The entrapped air will be carried in the upper portion of the runner, and the capacity of the trap must be sufficient to ensure that it can take the aerified portion of the incoming metal. As an extra precaution in this direction the runner to the castings has a step down from, and is at a lower level than the entry to the trap. (See Fig 1.)

The microscope shows that the hard spots are composed of what Dr. Stead calls the ternary eutectic of iron, carbon, and phosphorus, which has got extruded into a convenient air-hole. The film of oxide, which is to be seen round the hard spot, shows that there is a close relationship between it and the air-holes. At any rate, when the air-holes were got rid of, the hard spots likewise disappeared. From the time the foregoing method was adopted for dealing with these troubles over two years ago, there has been practically no complaint of either the one or the other.

Referring to the model, the basin at the bottom

of the gate is for the purpose of saving the mould from getting burnt away through the pouring of the metal. The metal that first enters the basin quickly loses heat and forms a cushion for that which is being poured in, and thus keeps the bottom of the mould from being in contact with fresh metal from the ladle. Moulds so constructed have been in daily use for months without signs of serious wear at this part. A riser or "flower" should always be used when the form of the castings permit it. The first metal which enters the mould has its temperature very quickly reduced, and if allowed to enter the casting is apt to create a chilled patch. The riser serves to divert this cooled metal past the casting.

As the writer does not believe that liquid pressure can have much effect on the moulds, he considers it best to have the parts held together either by wedges driven in or by some other equally rigid method. Two arrangements which had been used satisfactorily provided for the box being opened and the castings removed from the mould in the shortest possible time. The tables or stools on which the moulds with the wedges are placed have occasionally been broken through too forcible driving of the wedge, when closing up; but in no instance has one been known to give way under pressure exerted by the solidifying metal. It is not necessary to machine the faces of the mould so long as they have been carefully made and fit together close enough to prevent the metal getting into the joints.

There is some divergence of opinion as to the best iron to be used in making permanent moulds, but so far as cast-iron work is concerned, there is really no need for selecting any special mixture.

Distortion of the moulds resulting in the opening up of the joints has been another source of trouble to several workers. It is worth while pointing out that the distortion takes place when the moulds are out of use, and not during the casting operations, and particularly when a rigid form of closing is adopted. When the cast is finished the inside centre part of the mould is generally at a red heat, while the outside is comparatively cold. There is consequently a difference in the amount of contraction between the inside and outside on cooling, and which, if allowed free scope, will pull the mould out of shape. To prevent this the mould should be closed and the wedges driven home immediately the cast is finished, instead of being allowed to lie about loose. One firm, whose boxes had been left in this way until they had become practically useless, was able to bring them back to condition by running metal into them until heated up and then wedging them up as suggested.

The foregoing will indicate the principal difficulties which are encountered in working with iron moulds, and the manner in which these have been dealt with in the moulds themselves, to give satisfactory results. In the actual working of the moulds, and considering that speed of handling was of such vital importance, it was necessary to organise squads of men, each with his own particular duty for each set of moulds. Each man pouring metal required five or six attendants according to the size of the mould, in order that the operations could be carried through with any feeling of assurance in the results. These arrangements naturally make the process more costly than sand moulding, and its only merit lies in the superiority of the castings for a specified purpose.

For castings which have not to undergo machining and in which hard spots and patches may lie undiscovered, there is no doubt that permanent moulds could be much more extensively used than they are at present. In this case the mould is practically always ready for use, and as the attendants can be dispensed with, the cost of casting will be less than in sand work.

Discussion.

MR. BROUGHALL, referring to the author's remarks on the position of the chemist, said that apparently Mr. Riddell wished to make the foundry foreman responsible for certain things which he (Mr. Broughall) thought ought not to be put upon him. The lecturer put the chemist in an altogether inferior position. What he practically suggested was that the chemist should give the foundry foreman particulars of certain mixtures or the analyses of certain pig-irons, and leave it to the foundry foreman to use this information to produce definite results. That implied that the foreman would have to be responsible for the metallurgical side of the foundry work, and while he was quite prepared to admit that the foundry foreman ought to possess some metallurgical knowledge, he did not agree with the view taken by Mr. Riddell, because a foundry foreman had plenty to do to produce good castings. Moreover, he was in rather a different position compared with the machine-shop foreman. Foundry foremen had a definite day's work to do every day, and at the present time most of them were responsible for increased output, and had considerable difficulty as regards labour. If they had to look after these duties properly they had no time to attend to the technical side of foundry work. That part should be controlled absolutely by the laboratory. He would no doubt be told that all foundry foremen had not got a laboratory to depend on, but he was quite sure that all firms of any size should possess a laboratory, which would release the foreman from responsibility which never ought to be put upon him. Mr. Riddell stated that in his experience with permanent moulds he ignored chemical analysis entirely. He (the speaker) considered that was absolutely wrong, and could not help thinking that Mr. Riddell did not entirely ignore chemical analysis, for later on in his lecture he referred to two instances where he had actually taken an analysis for combined carbon. In one instance it was proved by the analysis taken that the metal being used in a permanent mould was altogether unsuitable for that purpose.

In giving some of his experiences, Mr. Riddell was good enough not to mention the name of a particular firm who had been giving advice to various foundries, respecting the production of fuse bodies in permanent moulds. He (the speaker), however, knew quite well that the firm to which he was referring was his own, Messrs. Alfred Herbert, Limited, and the particular advice referred to was that for which he (the speaker) had been responsible. Mr. Riddell's complaint about the advice given was in connection with combined carbon, and he thought in replying to these remarks it would be best if he read an extract from one of his reports, replying to a report made by Mr. Riddell. The extract is as follows:—

"I would say at once that to my mind Mr. Riddell is under an entire misapprehension as to our method of using permanent moulds, and in consequence I claim that the whole of his criticisms are entirely misplaced. Moreover, I

cannot help thinking that Mr. Riddell had not carefully read the pamphlet or he would not make us say things which really we have not said. For instance . . . Mr. Riddell says, 'It is something new, however, to be told to select a *pig-iron* for casting purposes from its combined carbon content.' We say nothing of the kind; our statement is that a *mixture* of iron must be used which is practically non-chilling, i.e., one with a low combined carbon content, etc., and we would point out that a mixture does not actually become a mixture until it has passed through the cupola. We should have thought that Mr. Riddell would have readily understood that we were referring to the mixture in the castings."

The speaker proceeded to explain that the advice given by his company was intended to show that castings made in permanent moulds should be low in combined carbon in order to prevent any chilling effect. Mr. Riddell had made a big point respecting the effects he claimed to have got, due to quick cooling, explaining the various stages the iron passed through during this cooling, and contending that the iron should be cooled at a definite rate if satisfactory castings were to be obtained. His (the speaker's) experience, however, showed that it did not matter how quickly the castings were cooled; in fact, every effort was made to accelerate the cooling by making the permanent moulds as massive as possible, so as to extract the heat from the metal in the quickest possible time. Mr. Riddell stated that there was no expansion such as the speaker claimed did take place directly after the metal was poured into permanent moulds, the author's theory being that pressure did not take place until the metal reached a temperature of 700 deg. Mr. Broughall contended, however, that an important expansion did take place at 1,130 deg., when the metal was in a liquid state. In most permanent moulds it was his practice to provide for allowing permanent moulds to give somewhat to this pressure, and if this was not done, in some cases a burst mould resulted. He referred to Mr. Riddell's method of annealing in sand and sawdust, saying that such a crude method did not appeal to him. It was altogether too slow if, as he understood from Mr. Riddell, the annealing took two days to complete. It was their practice to anneal quite a large quantity of castings, and the method adopted was to pack these in boxes with cast-iron turnings, which were put into a furnace and heated up to 800 deg. C., and then allowed to cool down.

The cutting speed of 150 ft. per minute, with a depth of cut of 5/32 in. mentioned by Mr. Riddell, on castings he had produced in permanent moulds, was nothing out of the ordinary, much higher cutting speeds having been obtained.

Mr. Riddell had given some very useful information regarding the small hard spots found in castings made in permanent moulds, and he was quite prepared to accept what had been said, but his (Mr. Broughall's) theory was that the hard spots were due to small pellets of metal breaking away from the stream of metal being poured, when the stream first came in contact with the bottom of the mould, and he believed that these pellets chilled immediately, and that in small castings there was not sufficient body of metal to re-melt them. The author, however, had gone to considerable trouble to thrash out this particular point, and he (the speaker) was quite prepared to give way to him. The theory put forward by Mr. Riddell regarding air holes was very interesting, and there was doubtless a great deal in it. By his own method of using permanent moulds, however, these small air holes bothered them very little, no special arrangement being made to get rid of the air in the moulds. He considered that although Mr. Riddell had done some excellent work in connection with the production of fuse-body castings in permanent moulds, that gentleman was working in an entirely wrong direction in attempting to produce, commercially, such castings in the type of permanent mould he was using. (Mr. Riddell: I grant you that.) It was, of course, absolutely necessary with this work to operate on commercial lines, and he was convinced that three-parts of the trouble which Mr. Riddell had experienced was due to him using the wrong type of mould. Personally, he thought that the moulds shown were of very bad design, and indicated that the lecturer had only limited experience in this particular class of work. Certainly, he (the speaker) would never be tempted to make castings in permanent moulds such as those shown. Moreover, it was obviously the wrong way to make these particular fuse bodies, and he considered that the foundrymen generally had never taken a sufficiently strong stand against the request that these fuse bodies should be produced in that particular form. If foundrymen who had been called on to produce these articles had insisted on them being made from the bar there would have been very little trouble with them.

He was very glad to hear the author say that there was no necessity for any special mixture being used in the making of the permanent mould. He personally had used ordinary mixtures, and always got good results. He admitted that if these moulds were made from hematite, better results still, as far as the life of the mould was concerned, would be obtained.

In regard to distortion of the permanent mould, continued Mr. Broughall, he could well understand this, and, in his opinion, it was entirely due to the bad design of the mould. If permanent moulds were made sufficiently massive, very little distortion took place, even after continued and prolonged use.

Referring to the fuse-body casting again, several firms had made these castings as shown by Mr. Riddell, and claimed to have got good results. A number of the castings were sent to the speaker in October last to report on, with the intimation that this particular firm was getting wonderful results, but the castings sent him proved quite the contrary, as the following report showed:—

"I have had the whole of the castings sent by Messrs. ——— machined, and am not at all surprised to find that there is hardly a good one amongst them. I am quite satisfied that Messrs. ——— have gone into this matter very thoroughly and very carefully, and have done their utmost to produce good castings by this method. I am still, however, convinced that the proper way to produce small castings such as these, from a permanent mould, is by casting bars of suitable diameter, such as is our practice."

If anyone attempted to make small shaped castings in permanent moulds, he was quite sure that they would have a lot of trouble. In the speaker's opinion, the proper method to adopt was to make castings in permanent moulds of as simple an outline as possible. On these lines his own firm had produced thousands of tons of castings from permanent moulds with extraordinarily good results, and by this process many of the troubles that Mr.

Riddell had had to contend with entirely disappeared. They were casting bars from 1¼ in. to 4½ in. diameter, and in shorter lengths up to 10 in. diameter. His remarks were based on years of experience and related to regular work, and not at all experimental work.

Mr. H. L. Reason said that, with reference to Mr. Broughall's remarks respecting fuses made from bars, as against those from bodies cast to shape in permanent moulds, he quite agreed that making fuses from bright cast-iron bar was the best method; but they had to consider the large plants of machinery which were producing these fuses in brass. To adopt Mr. Broughall's suggestion, large lathes to take two and half-inch bar through the headstock would be required, and this introduced a very important question. He believed the bulk of fuses made in this country were produced by private firms, and it was only to be expected they would, as far as possible, only purchase machinery that would be of service to them after the war. Generally speaking, as an after-war proposition, it would be far easier to find work for the type of lathe now producing the brass fuse than it would be for the large lathes required to make the fuses from cast-iron bar. To produce iron fuse-body castings to meet the specification of forty tons compression, 8 per cent. depression, machining speed 150 ft. per minute, cut 1/16 in. deep, feed 0.2, Brinell hardness 150 to 160, was no easy matter. The difficulties in casting bodies to shape in permanent moulds were not met with when casting bars in permanent moulds. He thought the result obtained by Mr. Riddell with permanent moulds was very good, and he considered it an achievement to produce castings by this method to give regular uniform results. Speaking from experience, he had obtained the best results for sand castings. He had machined both "semi-steel" and ordinary cast-iron which met the specification with very good results. The analyses of same were as follows:—

	No. 1.	No. 2.
Total carbon	2.9	3.78
Combined carbon	—	0.06
Graphitic carbon	—	3.72
Sulphur	0.12	—
Phosphorus	1.35	1.29
Silicon	2.0	2.47
Manganese	0.6	0.77

From the following it would be noticed how silicon affected the compression tests:—

Silicon. Per cent.	Tons compression.
3.2	4
2.8	5
2.7	6
2.5	7
2.4	8

As to the production of non-ferrous castings in permanent moulds, Mr. Reason continued, he had had no experience beyond making chill bars for stamping and fuse bodies. To produce brass fuse bodies or similar castings in permanent moulds satisfactorily, it was necessary to have a sand top for the riser, so that the metal in the riser remained molten sufficiently long to feed the body. As stamping or pressing was the most economical way of producing brass fuse bodies, as soon as sufficient drop hammers and power presses could be obtained, the method of casting was dropped.

With reference to the foundry chemist, he could not quite agree with Mr. Riddell. Science, if properly applied, would not only help to reduce the amount of defective castings made, but would help to improve the production, and he was certain if this country were to hold and maintain first place in the markets of the world they would have to drop a lot of the rule-of-thumb method and attack works troubles on scientific lines. The managers of large works in future would not only have to be engineers, but would require sufficient knowledge to control a laboratory, as it was only by this means that the highest efficiency could be obtained.

The President said there were a number of points on which he was quite in agreement with Mr. Riddell. In nearly all cases it was found to be the best practice to use what was commonly called a skimming gate to get sound, clean castings in a permanent mould, probably for the reasons stated by Mr. Riddell. Also, it was found that, so far as shells were concerned, a certain degree of hardness was more important than the mixture, and this could be attained by allowing the casting to remain in the mould a definite time, which varied with the mixture used. Mr. Broughall had pointed out that annealing by Mr. Riddell's process was both a long and uncertain work. This was obviously so. As far as his own experience went, while the cutting speed mentioned might not be attained, if the castings were taken out of the moulds as hot as Mr. Riddell stated and piled together, they should re-anneal themselves sufficiently to be either drilled or turned, if cast of a proper mixture. He was sorry that the treatment of the subject had not been broader, but had been merely confined to fuse bodies; as foundrymen they had not devoted time to perfecting and extending the method as they might. That the Germans were using cast-iron shells there could be little doubt. While there was some doubt as to the life of the permanent mould for iron castings, this did not apply to the same extent in non-ferrous castings. Quite a number of firms were making pistons and oil pans, etc., in an alloy of aluminium. It was claimed that the tensile test was increased from 20,000 lbs. in sand to 25,000 lbs. if cast in permanent moulds, and that the metal had a smooth surface with exceedingly close grain which was practically impervious to water and oil.

Mr. F. J. Cook said that apparently Mr. Broughall was not thinking so much about chemists as about metallurgists. If Mr. Riddell intended his remarks to apply simply to chemists, he was undoubtedly right, because some chemists had caused a great deal of trouble through being merely chemists and not metallurgists. Undoubtedly a chemist who was a metallurgist could be of the utmost use to a foundry, relieving the foundry foreman or manager of a great many of his difficulties. With regard to permanent moulds, there was a very large field of mixtures available for many cast irons, but when they came to higher temperatures for steel that was altogether a different matter, and they must have the metal of a very definite composition if they were to get what was wanted. He had in mind particularly the casting of steel shells in a mould. With too much hardness—for example, such an iron as No. 4 hematite—they would probably find that it would crack the first time it was subjected to strain. If they got a softer iron they would get elasticity, but it was very likely to disintegrate, and if they

did not use hematites the shells were practically useless. The life of those moulds did not extend beyond twenty casts, and as they cost about a sovereign the mould cost of every shell was at least a shilling. With grey iron possibly it was not necessary to work to such a close analysis. He believed in getting the shells out quickly, and there was something to be said for that on the chemical side. Irons of a certain chemical analysis would allow longer time to get them out, and, of course, a man must have a certain amount of time for that purpose. The best policy was to find an analysis which would give the longest time to remove the castings from the moulds. He had not had a very wide experience of permanent moulds generally, except in their application to chills, which he had had to do with chiefly in connection with cylinders. They could not get the casting out very quickly, and, therefore, the analysis had to be watched very closely, or they got a chill instead of a dense structure which was grey. One of the elements to watch had always been the manganese. If they got high manganese they got a chill. With lower manganese, other things being equal, the chill did not appear, and they got a soft structure.

MR. A. HARLEY said that, notwithstanding Mr. Broughall's strong criticism, with much of which he agreed, he had thoroughly enjoyed the Paper. Mr. Riddell, like many foundrymen, had found himself up against difficult problems, entirely due to the war, in being suddenly called upon to make castings described, representing an entirely different class of work to what he and his staff had been accustomed. He sympathised with him in his difficulties, and the success achieved was highly creditable.

MR. RIDDELL, replying, welcomed Mr. Broughall's criticism, and would have been much disappointed if he had not taken up the attitude which he did. As Mr. Cook had suggested, the author was dealing with the chemist purely as such. He acknowledged the value and importance of the chemist, but what he objected to was the putting of responsibilities upon him for which he was not qualified as a chemist. He felt strongly on this point, because, by making a fetish of the chemist and a panacea of chemistry, as had been done in many quarters, ironfounders had been hampered, and the output of munitions and other stores restricted. In ninety-nine cases out of a hundred the user of cast-iron had not the slightest interest in the chemical contents of the casting, so long as its physical properties adequately met his requirements. Mr. Broughall's people deserved all praise for their open-minded and public-spirited action in so freely giving out the benefit of their long experience, in the pamphlets to which he referred. At the same time, there were many views expressed in it which he considered wrong, and some of them unfortunate, in so far as they had created unnecessary difficulties to the inexperienced. He did not think that Mr. Broughall's explanation about combined carbon met the complaint. The statement objected to was in these words :—"The most important point (*sic*) in connection with the production of castings in permanent moulds is that a mixture of iron must be used which is practically non-chilling, i.e., one with a low combined-carbon content, say about 0.275 per cent. and a silicon content of about 2.75 to 2.90 per cent." He understood Mr. Broughall to explain that this advice was intended to refer to the combined carbon in the casting. If he had understood Mr. Broughall correctly, the paragraph did not say what it meant, and if it did, it would only have added to the worries of the ironfounder to discover the mixture that would produce castings with the composition advised. Concerning Mr. Broughall's criticism of the design, he was not sure whether he referred to the design of the casting or of the moulds. If the former, he agreed with Mr. Broughall, because casting in rods, which he himself had done, was a simple matter in comparison with the design shown; but there was no option as the castings had to be made to shape stipulated. His purpose in presenting the Paper was rather to explain what was involved in using permanent moulds, and to show the methods adopted for meeting the difficulties. With regard to the design of the moulds, they were easy to make, simple in construction, and served to produce satisfactory castings. No doubt the design might be still improved, but he was only anxious to place his experience, so far as it went, at the disposal of his fellow-founders. As for the method not being a commercial proposition, that depended on the value placed by the user on castings so made, and the price he was willing to pay. He had already indicated that, in the present instance, the method turned out unprofitable, but having taken on the task, he had made up his mind to solve the problem. While there had been financial gain, there had certainly been also considerable technical gain, from the experience, which had already been of advantage in many ways. He (Mr. Riddell) considered that spring fittings on moulds constituted unnecessary and (in view of Mr. Broughall's explanation of distortion) most undesirable attachments. He would prefer, instead of affording facilities for the moulds to go out of shape, from the causes mentioned, to use rigid methods of closing, which would prevent that particular form of distortion.

ELECTRIC FURNACE WITH AUXILIARY ELECTRODES.—A special feature of the Booth-Hall electric furnaces is that each furnace is fitted with an auxiliary electrode in addition to the one (single-phase), two (two-phase), or three (three-phase) main top electrodes. In the larger sizes the auxiliary electrode is vertical and passes through the roof like a main electrode, but in the smaller sizes it passes through the door at an angle. In the bottom of the hearth a wrought-iron gridiron is embedded, faced with refractory material, to serve as bottom electrode. When starting a heat with a cold charge a pawl on the auxiliary electrode is released, allowing this to drop and rest on the charge. On turning on the current in, say, a two-phase furnace arcs are formed between the main electrodes, and the charge begins to melt under the heat thus produced. The auxiliary acts as a common neutral, and consequently no arc is produced and no metal melted immediately under it. As soon as sufficient molten metal has accumulated on the hearth to make it conductive of current the auxiliary electrode is withdrawn and its porthole closed. The transformer connections are so arranged that each phase has its own separate circuit. It is claimed by the makers that the use of auxiliary electrodes assures a contact with the charge when the heat is being started, and there is no bottom contact touching the bath, which may be covered with slag. This system of electrodes, it is further claimed, also precludes the possibility of arcs in series above the bath. No water-cooled contacts are used on any of these furnaces.

Physical Constitution of Moulding Sands.

Prof. W. G. Fearnsides, M.A., Sorby Professor of Geology at Sheffield University, gave a lecture on "The Physical Constitution of Moulding Sands" before the members of the Sheffield Branch of the British Foundrymen's Association, on January 18, when Mr. John Little, M.I.M.E., presided.

Prof. Fearnsides said that the subject, as announced, was a vast one, and that although during the last three years he had devoted a good deal of time to the study of the raw materials used by moulders, the main conclusion which had impressed itself upon his mind was that the art and practice of mould-making is at present far in advance of the available codified scientific knowledge of the subject. He recognised, however, that the study of moulding sands was one very pertinently connected with the still larger subject of refractories, and it was because to that extent it lay within the purview of the newly-established Department of Refractories at the University, that he had accepted the invitation to address them on a particular aspect of the moulding-sand question.

A year ago he had talked to them about the changes of physical state unaccompanied by any appreciable changes of composition which take place when quartz sand is raised to steel-melting temperatures. On the present occasion he would consider the constitution, i.e., the composition and essential texture, of sands which can be built up into moulds which will contain, and control the form of, metal castings poured into them at a very high temperature. The following is a summary of the lecturer's remarks:—

The most essential constituent of moulding sands from the chemical point of view, is silica, and I do not propose at the moment to discuss the behaviour of "compo" or of any other of the moulding mixtures which contain less than about 80 per cent. of silica. I wish therefore first briefly to recapitulate some of the conclusions advanced when lecturing to the Association on "Silica as a Refractory Material" a year ago, about what happens when the temperature of an aggregate of quartz-grains is gradually raised to steel-melting temperatures. Quartz which is found as sand-grains on the seashore or as a constituent of other sands, sandstone rocks, ganisters or quartzites, can generally be referred back to a more primitive source as a constituent of some igneous rock, such as granite, and it is probably safe to assume that over 90 per cent. of the quartz-grains in existence represent chips of quartz derived from the mechanical breakdown of igneous rocks, in which that quartz had crystallised during the solidification of a hot molten magma. It is not known at what temperature the quartz finished its crystallisation in igneous rocks, but there is good reason to believe that because of the mutual inter-solubility of the various silicate minerals, quartz, felspar, mica, etc., of which igneous rocks are composed, the temperature would be far lower than the melting point of any one of those minerals when heated by itself. It is probable that in most granites the temperature at which the quartz crystallised was lower than that at which quartz when heated begins to pass over into tridymite, which temperature, according to the work of Fenner and his associates at the Geo-Physical Laboratory at Washington, is a little lower than 900 deg. C. Probably when it crystallised, the quartz formed as beta (β) quartz, but subsequently during the cooling to ordinary temperatures, all naturally-occurring quartz has been converted into the alpha (α) modification.

Alpha-quartz, whether in grains or in larger pieces, when heated to 580 deg. C., undergoes an abrupt volume change. When a silica brick is heated slowly through that temperature, it can generally be heard crackling, and if in works one took the trouble to examine the surface of a silica brick, one end of which was being heated while the other remained cool, it would be noticed that as the zone of redness travels along the brick, there moves in advance of it a black-hot zone over which such dust as happens to be floating in the neighbouring air tends to settle, and become adherent. Probably the attraction of this dust is due to the considerable electrical disturbances which are set up as the alpha-quartz undergoes its change over to beta-quartz, and there is good reason to believe that the change accomplished at that temperature is a fundamental molecular change. In such unstable sand-aggregates as those formed by ramming moulding sand into position to form the face of a mould, there is no temperature more critical or more difficult to pass without disturbance of the relative position of some of the sand-grains, and consequent break-down of the built-up structure of the mould, than the temperature of the alpha to beta change of quartz. Core-makers, when baking their construction, therefore do well to keep the ovens at temperatures lower than 550 deg. C.

Heated further to some temperature in the neighbourhood of or above 900 deg. C., beta-quartz in its turn becomes unstable, or rather meta-stable. If kept in contact with any suitable flux in which it is slightly soluble at that and higher temperatures, it dissolves, and as soon as the solution which adjoins the dissolving grains has become saturated with silica, there begins to crystallise from the solution another and totally different form or modification of crystalline silica to which, by reason of the refractive index of the product, the name tridymite is applied. This conversion of quartz into tridymite, which continues just as rapidly as the diffusion of silica through the super-saturated flux will allow, is a process essentially distinct from, and always slower than, the direct process of inversion of alpha- into beta-quartz, but similarly is accompanied by a very important volume change. As found in nature, the density of quartz is 2.65, while that of tridymite varies between 2.28 and 2.33, and though we are probably not justified in assuming that the volume change which occurs when the tridymite grows at the expense of the beta-quartz is quite so great as the 14 per cent. which such figures as these might indicate, the experience of those who work acid Siemens and other furnaces constructed of silica bricks has taught them to expect and allow for an expansion of the silica in bricks which have been already partly tridymitised in the process of manufacture, by more than 5 per cent. In the ordinary application of moulding sands to the purposes of the foundry, the period during which the silica of the sand is maintained at temperatures so high as a bright red and a yellow heat, is so short that there is little opportunity for the tridymite conversion change to operate, and to foundrymen whose main

business is with moulds and the castings which come from them, the properties of tridymite are of comparatively small importance.

At temperaturs above 1,000 deg. C., silica, whether it be the meta-stable quartz or the tridymite into which that quartz is converted, continues to expand with rise of temperature, and at the same time loses its heat-insulating properties, and becomes almost a good conductor. If heated, as by contact with cast metal, so quickly that it continues in the form of meta-stable quartz to the temperature at which low-carbon steels begin to melt, and then chilled from that temperature, the silica is found to have vitrified and lost all traces of crystalline structure. The silica glass formed thus has, when cold, a density which is little more than 2.0. More slowly heated and kept for a longer time at temperatures between 1,470 deg. and 1,600 deg. C., silica suffers a third polymorphic inversion, and crystallises as crystobalite, which, according to the work of Fenner, is the crystalline modification of silica proper to the highest temperatures, and only becomes vitreous when the temperature is raised above 1,625 deg. C. Because the coefficient of expansion of vitreous silica is almost identical with that of the metallic skin of many castings, vitreous silica usually "burns on" to the castings against which it is formed, and the conversion of the quartz grains of facing sands into silica glass is one of the most serious of the troubles which makers of small steel castings have to meet. With heavier castings, by which the silica is kept hot longer by the heat conducted from the greater bulk of hot metal, there are other troubles; but since in part the quartz changes over into crystobalite which has a different coefficient of expansion, and also one or more low temperature inversion points, passing which it tends to crack during the cooling process, the sand itself does not burn on so tightly, or, if it does adhere, is more easily removed in the fettling shop. Neither vitreous silica nor crystobalite is at all common in the burnt-sand product which accumulates and forms the floor sand in iron foundries.

So far I have considered only the physical properties of the actual quartz sand-grains of which moulding sands primarily consist. But though these grains of pure silica in general form something between 80 and 90 per cent. of the sands used in steel foundries, it must not be forgotten that the remaining percentage of those very various materials which collectively form the "bond" are of at least equal importance in determining the specific moulding properties of the sands as used. When moulding sands, as received from the quarries, are being blended and made ready for the moulder's use, there is no operation more delicate than that of tempering the sand by adding the requisite proportion of water. Observations made in a good many foundries lead to the belief that more castings are spoiled by reason of the presence of an improper proportion of water in the facing mixture than from any other cause. There is much to recommend the American practice of routine hourly determination, and chemist's control of the water percentage in a steel-foundry sand mixture, keeping it always between 7 and 9 per cent. At various times I have persuaded friends in this country to determine the water percentage in their own mixtures, and though the variation was more considerable than between the limits mentioned, I am satisfied that about 8 per cent. of water is about the soundest practice for most "green" moulding sands. In passing, a word or two may be said about the way in which the water of the bond performs its function. The effect of water might be illustrated by instancing the practice of careful hostesses when tea is being handed round at a reception, of pouring a drop or two of water into the saucers as a means of preventing the cups from sliding off. In the same way those who have developed photographic plates and poured off the developer have doubtless noticed how difficult it is to separate the glass plate from the dish so long as a drop of liquid as a water-film remains to hold the two together. The adhesion in the cases cited depends on the circumstance that both glass and porcelain are substances which water likes to wet. There are, however, other kinds of materials which are not so readily wetted either by water or by other kinds of liquid. Globules of mercury can be rolled about on a wooden table for an indefinite period without wetting it, but woe betide the man who tries to gather quick-silver in a silver-plated spoon. A tar-sprayed road sheds the rain because water cannot wet the tar, which itself has already wetted and formed a waterproof coating over all the surface of the road-metal stones.

In sands there is in the grains of alpha-quartz, a material which pure water will hardly wet, but over which water which has already changed its surface tension properties by dissolving a small quantity of other minerals, will spread with moderate avidity. Thoughtful people who have chosen sandy or light loam soils as sites for their dwellings have taken advantage of this physical property of quartz which controls the free drying of sandy soils, while those who complain of the continual dampness of clay even in summer weather, suffer from an environment over-rich in mineral substances which water loves to wet. All the mineral substances which form the bond of natural moulding sands are materials which are readily wetted by and soak up water, and when isolated and remixed with excess of water give emulsions or solutions which spread with avidity over the surface of alpha-quartz.

Among the well-recognised bonding substances which retain water in the manner just suggested, and by their presence in comparatively small proportion determine the distinction between those clean, sharp sands which are useful for parting and the velvety moulding sands which separate so unwillingly from one's palm when a handful of them has been tightly gripped, the various more or less hydrated silicates of alumina may be given precedence. These are most useful when most highly hydrated; and moulding sands not too fine in grade, which contain a comparatively large proportion of colloidal "clay substance," are much sought after and an increased home supply of such is greatly to be desired. It is because the importance of the influence of clay substance has been recognised that the American practice of making synthetic or artificial moulding sands by mixing together clean, sharp silica sand with a convenient proportion of shredded fireclay, has grown up.

Hardly less useful than colloidal silicate of alumina is that more generally and completely collodial substance known as ochre, which is a naturally occurring mixed oxide and hydroxide of ferric iron. As found in natural moulding sands, iron hydrate generally owes its formation to the breakdown and oxidation of ferrous carbonate or ferrous silicates, which during the process of the evolution of present day topography have come within the influence of atmospheric weathering. The best of these sands are quarried from locations

where the chemical reaction which gives rise to the formation of the ochre colloid is actually progressive at the present time. Whether by the admixture of a powdered ferrous mineral to a quartz-sand aggregate, and subsequently allowing opportunity for the oxidation to take place, there will be evolved an economically possible process for the manufacture of an iron-bonded moulding sand, does not yet appear. When the need for such a material becomes more generally recognised it is probable that powdered limonite of some such quality as could be obtained by the dry milling of Lincolnshire or Northamptonshire iron ores, will be added to improve certain highly siliceous sands which are otherwise suitable, in much the same way as the fireclay is added in the American practice already mentioned. It is probable that under other conditions, colloidal mixed hydrates of iron and alumina, which occur together in the form of bauxite, could be added with advantage as a bonding material in moulding sands.

Of other naturally occurring mineral substances which I have noted as playing the part of bond in moulding sands as at present used, carbonates of lime and the molecularly mixed carbonate of lime and magnesia are worthy of mention. In the steel foundry both calcite and dolomite are looked upon with grave suspicion, but in foundries where small castings of brass or iron are made, and it is essential that the water content of the moulding mixture should be kept constant, both are quite usual constituents of the finest grade of facing sands. All the rhombohedral carbonate minerals wet with avidity when mixed with water, and if with the raising of their temperature the carbonates lose their carbon dioxide and are partly or wholly converted into oxides, the hydroxide which results from the slaking performs useful service as a colloid. At temperatures higher than the pouring temperature of cast iron, both lime and magnesia attack silica and fusible silicate slags result. If, however, only silica and lime are present the rate of slag formation is too slow for it to give the trouble even in sands which are to be used in the moulding of steel castings. Recent experiments, in which particularly hot steel was run into moulds which had been built up of the standard sand-lime mixture used in the manufacture of sand-lime bricks, suggest that in the future more will be heard in our foundries of high silica sand—calcium hydrate mixtures—as material suitable for the building up of certain kinds of cores. There is no doubt that such mixtures containing up to 5 per cent. of lime are quite sufficiently refractory to serve the ordinary purposes of most steel foundries.

Outside the ordinary run of natural or artificially added mineral bonding materials come the various organic and carbonaceous binder substances which are so generally used in the building up of smaller cores. These, like the mineral substances with which they are in competition, are generally non-crystallisable and probably colloidal products, are readily miscible with water at ordinary temperatures, and give solutions or emulsions which spread readily over and completely wet the surface of the grains of quartz. Breakdown products derived from cellulose, resin, starch, or sugar, are the materials most generally in favour, and all these have the property of decomposing with evolution of combined water when heated, and leaving behind a residium which is exceedingly like coke.

As regards the question of the mechanical constitution of moulding-sand aggregates when already prepared to meet and contain the molten metal, it is well-known that most of the best natural sands and all standard green-sand moulding mixtures which have yet come within my notice, are alike in consisting of a large percentage of comparatively large quartz-grains, a very few grains of intermediate sizes, and a fair percentage of "clay" particles too small to be worthy of the name of grains of sand, the great majority of which consist of some or other of the various partly colloidal bonding substances which have been enumerated above. When such an aggregate is rammed into position, the major sand grains ought to make up a structure like that of piled-up pebbles on a sandy beach, the minor grains not being present in quite sufficient quantity for the space between the pebbles to be completely filled. Air-spaces between the sand-grains are needed in the built-up moulds in order that the gases given off by the casting when the metal solidifies may find a free path through which they may escape, and, further, in order that the steam formed by the boiling off of the water, which is so essential a constituent of the green-sand aggregate, may not have to force its way back and out through the metal and give rise to pin-holes or honey-comb structure within the casting. Round-grained sands pack less closely, *i.e.*, with wider air spaces, than sand-grains which are angular; and therefore if used for moulding purposes a round sand can carry a greater proportion of bonding material admixture without the pores between the grains becoming completely clogged, than can a sharp and angular sand.

Following a little further the analogy of the tea-cup held in place by a drop of water upon a saucer, if there is a little clay, ochre, or other colloidal substance associated with and enclosed within the water drop beneath the cup, what happens to the cup and saucer with the wetted mineral particles aggregate when the water dries away? When by evaporation the water film shrinks into its final hiding place it pulls with it the minor wetted mineral grains, and only as and when these become wedged between the sides of the narrow fissure do these become stranded and left outside the retreating water film. Retreating thus the outward-facing surface of the water becomes ever more and more acutely curved, and accordingly the rate of evaporation must be ever less and less. If when most of the water is gone and the curvature of the remaining droplet has become very small indeed, an attempt be made to lift the cup from the saucer, the probable result is that the saucer is actually raised a little way along with the cup. The water-film, with its increased curvature, has become effective in sealing a potential vacuum, and it is by the operation of atmospheric pressure that the saucer is supported. When the seal is broken, one ought to be reminded that there is an optimum quantity of water for securing the closest adhesion of the china pieces with which the experiment has been performed. The behaviour of water-films in a water-bound macadam roadway is similar. In dry weather in summer such a road becomes dry and dusty, and passing traffic breaks up the surface, which being deficient in water has no strength. After a thunderstorm, or, still worse, towards the end of a spell of wet weather in the autumn, or after a winter's frost, the same road sodden with water is similarly rotten and devoid of strength. Intermediately when neither muddy nor yet dusty that same road may be so conditioned that it bears the traffic of a succession of three to six-ton motor lorries without being stressed beyond

its elastic limit or suffering damage or even any appreciable wear.

To every aggregate of materials bonded by water-films there is then an optimum proportion of water, which proportion differs widely with the grade and chemical constitution of the aggregate as bound. This proportion ought to be investigated and determined experimentally for every standard grade of moulding sand. The writer little doubts that the recorded troubles at the Tower of Babel were due to the use of unburned waterbound clay bricks, built up on a foundation where, with the seasonal rise of the ground water level, the water-films which held together the bricks which formed the lower courses gained access to and by capillary action soaked up more water than was good for them, so that in due course the whole structure came tumbling down. Moulding sand left out in the rain behaves similarly, and it is the business of green-sand mould-makers to work up their sand with just so much water that it has rammed strength enough to remain in proper position until by further drying it shall have increased in strength sufficiently to stand up to and resist the wash of the molten metal. Immediately after the moment of casting, when with rise of temperature there is progressive further dissipation of the moisture present, it is desirable that the content of water in the mould face, and also in the sand which lies behind that face, shall have become less than the proportion of the optimum, so that when the pull, which comes with the setting and contraction of the cast metal, is transmitted to the sand, there are no water-film tensions to resist it, and the sand can therefore "give."

Though it is important that the water which holds the green-sand mould together should as far as possible be boiled off and driven out of the sand aggregate before the casting begins to pull, it is equally important that the faces of the moulds should not begin to "merl" until the metal is at rest against them. As is well recognised by every chemist, although in the open water boils at 100 deg. C., water-films lurking in crannies between the sand-grains (which by the drawing in of the smallest grains and colloidal particles become effectively narrower as the water evaporates) may persist to temperatures quite 200 deg. higher, performing their function of binding the grains together all the while. Between 300 deg. C. (at which temperature the last of the water-films are generally dissipated) and the pouring temperature of iron and steel, there is a long temperature interval, and therefore a time period during which the structure of the sand aggregate has to be supported in another way. What precisely is the mechanism of the transmission of the supporting stresses during this interval—which is always passed through during the minutes when metal is being fed into the mould—has never yet been demonstrated. But it is permissible to quote the analogy of a mortarless wall built up by a skilful mason of boulders (the sand-grains) with little stones and handfuls of earth (the mineral bonding material) wedged or thrown into the nicks and spaces between the stones to prevent them from slipping out of position, and keep the structure steady, almost strong. It is the drying back of the water-films, which, as their surface recedes into the crannies between the sand-grains, push the wetted particles of bond material within and before them, and thus secure the tight wedging of these particles in positions where they perform this most desirable mechanical service. It is therefore of first-rate importance that the bond of every moulding sand should contain a proper proportion of fine-grained material and include some particles of colloid which water cannot fail to wet.

Wedged thus, the mechanical structure of an otherwise unsupported sand face must remain unstable until, at a very much higher temperature, either the actual fusion of the bond materials or the chemical interactions proper to these high temperatures allow neighbouring particles reacting together to provide the materials for the formation of a flux. Probably during the short time period involved in the filling of a mould with metal there is not sufficient time for melted materials or fluxes thus produced to spread through the whole body of the moulding sand, and it is not until the casting is already cooling and the contracting metal begins to pull that the slags, which, like water-films at lower temperatures, segregate to the sand-grain contacts, give their added strength to the mould aggregate. At this late period, as we have already seen, strength in the sand aggregate serves only to resist the pull of the metal, and is undesirable. In choosing moulding sands for any particular purpose it is therefore important, either by analysis, or, better still, by test of a sample of the actual material suggested, to ensure that up to the temperature at which the metal is poured the sand is sufficiently refractory and does not begin to melt. Though up to the temperature at which iron castings are run the selection of sands which are sufficiently refractory gives little trouble, and almost any sand of suitable grade suitably bonded can be made to serve, in foundries where steel casting low in carbon are manufactured it is quite otherwise, and because of their fluxing properties it is very necessary that the moulding sands adopted should not contain more than the minimum workable quantity of any kind of mineral bond. Probably it is because of the troubles due to pulls determined by these new formed slaggy binders, which, whenever superabundant, bring with them a host of those other troubles collectively spoken of as "burning on," that the practice of using, especially in core making, various organic substances in association with the purer qualities of silica sand in preference to naturally-occurring moulding sands, has grown up. Like the mineral bonding materials discussed already, the various organic binding materials when the sand aggregates are dried or baked, retire into and fill the crevices around the points at which the neighbouring quartz grains make contact, and so produce a built-up structure which is mechanically strong. With further rise of temperature above the boiling point of water, the organic core-binding substances do not in general evaporate away, but instead, as the temperature rises, give off certain vapours and begin to char. Charring, they boil up and form a sort of friable coke, which, even at steel pouring temperatures, does not react with the grains of silica, and therefore cannot form a slag.

Though by the use of highly siliceous refractory sands, bonded with organic by-products obtained from wood-pulp, paper, flour, or sugar mills, it is easy to avoid slagging of the sand aggregate within the mould, it is not so possible to ensure that the outermost layer of the sand-grains will not themselves burn on and become embedded in the skin of the castings, especially if the metal is low in carbon and has been "hot run." The economic effect, i.e., fettling shop charges, of such burning on is however a matter controlled at a much lower

temperature by the relative coefficients of expansion (or contraction) of the metal and the burnt silica or silicate slags which form the mould skin, and is a question not yet completely understood.

In leaving this matter and with it the equally important and difficult questions of the influence which the thickness of the backing and the thermal conductivity of the sand aggregate has upon the extent of burning on, to be dealt with by others, the writer desires to suggest that the difference between the parts of a mould skin which comes away cleanly from a steel casting and other parts nearer or further away from the runner where the skin is hard burnt on, may depend upon the distinctive difference in physical properties between uncrystallised glassy silica and crystobalite. Vitreous silica has a coefficient of expansion sufficiently nearly identical with that of several kinds of steels to remain adherent when the castings cool, while crystobalite, besides having a different coefficient of expansion, undergoes a sudden change of volume at a comparatively low temperature. Change of volume in one constituent sets up stresses in the aggregate of which it forms a part, and so secures that non-compact aggregates conveniently fall to pieces when the temperature comes down.

Postscript.—In going through the verbatim report of this lecture, and making the notes taken ready for the press, it has occurred to me that there will be some readers who may regard this dissertation upon the capillary properties of water in their relationship to minerals and the polymorphic changes undergone by crystalline silica with rise or fall of temperature, as of academic interest only and as out of place in an address to practical foundrymen. In my opinion such criticism is not justified, and in setting out thus my considered opinion upon certain difficulties which have been brought to my notice when visiting the foundries, I would like to add that I am convinced that were the physical properties of the mineral substances I have dealt with as well recognised in their inter-relationships with each other by those who have laboratory knowledge, as by the foremen who overlook the daily routine of the steel foundries of this town, Science in this matter would be in a position to give effective help to Industry, and with intelligent understanding of all processes would come considerable reduction both of the standing charges in the foundry, and more especially of needless excessive labour costs incurred in the fettling shop.

Discussion.

Dr. Boswell (Liverpool University) said that for some time before the war he and other investigators had been considerably interested in sands and their properties and industrial uses, and on the outbreak of the war, from being purely academic, at one bound this question became entirely economic. The whole question of refractories was one of the outstanding examples of the value of pure science as applied to industry. Much of the work on the conversion of quartz had been, and was still, in America a matter of pure scientific investigation, but it just happened that it applied, among other questions, to the subject of moulding sands. One or two facts had come out as a result of much inquiry into moulding sands. He wished to say right away that people who had been dealing with moulding sands, particularly in steel casting, for years, knew far more about the actual conditions than ever scientists could hope to find out. They had come to this point: so long as the materials they had been using were still obtainable they could go on the results of their experience, but when, as on the outbreak of war, many of the sources of their supply were cut off, and the reasons for the success of certain materials remained unrecognised, except by the very long process of continued trials and errors, it was impossible to find suitable substitutes in this country. Such industrial experiments could not be carried out during war-time.

When the Ministry of Munitions asked him to take up this question of helping the British manufacturer to find suitable supplies, the first thing he endeavoured to do was to examine as closely as possible the properties of those sands which had been in use. Many of the most successful materials were those which had been imported from abroad. Next, as geologists and knowing the British formations pretty well, the best thing they could do was to endeavour to find supplies as near as possible similar or equivalent to these successful ones. That was a task, he was sure they would agree, that ought to have been taken up twenty or thirty years ago, and not under war conditions, when the testing of likely supplies and experiments occupies time wanted for other purposes. They had first to tackle the questions empirically, and naturally sought out the results obtained by the ordinary methods of analysis of sands. All people interested in moulding sands had made chemical analyses of sands, and had come to the conclusion that these were of very little use. There were other desirable qualities in moulding sands, as well as that of chemical composition. It appeared to the speaker that the case of the common plum pudding was analogous. An analyst might say exactly what were the chemical components of the plum pudding, but would be very far indeed from being able to make one. So with moulding sands, they might similarly take a bulk analysis of moulding sand, and yet be little nearer the discovery of those properties which were essential in sands used in the foundry. They had heard, for instance, what Prof. Fearnsides thought of the importance of the water bond, and with those opinions he cordially agreed. They would notice that no material was mentioned as filling the intermediate spaces. To pack the spaces of any moulding sand would so reduce its permeability as to hold the gases, and would thus prove very harmful, and it was for that reason that clay could not be used.

Coming to the mechanical analysis, and determination of the size and quantities of the particles present, they found what at first appeared a very remarkable thing; but after looking at it from a moulder's point of view, it was not at all remarkable that these mechanical analyses showed that the higher grades (sand as understood by the geologist) were always abundant. Material greater than a quarter millimetre, or about 1-100th of an inch, was most desirable, and in most standard moulding sands the percentage was usually between 60 and 70 per cent. Then there was also a good deal of clay grade material. Of dust less than 2,500th part of an inch in diameter, there might be as much as 10 or 12 per cent. in the best moulding sand. The intermediate qualities of such silt stuff as fills our estuaries were practically absent from every one of the high-class moulding sands examined. These facts had a very simple interpretation in the works. The coarse sand enabled the mould to remain open, while the fine

clay bond held up the structure, and the particular material which would pack between the other grains and prevent the gases escaping was absent. Such a mechanical composition was very desirable, and the recognition of that circumstance enabled them to begin their further search for suitable supplies. In that connection it might be interesting to mention that he had recently made an analysis of the material supplied from Trinidad, a pitch material full of grains of limestone—a natural road dressing, which would give a compact and hard surface through which no water could pass. When they dissolved away the pitch and separated out the sandy material left behind, they found that the sand was evenly spaced over all the possible grades—there was about an equal amount of each size—and the whole mixture shaken together simply packed into one tight mass—a very desirable quality in sand required for a top road dressing, but just the opposite to what was wanted for a moulding sand. It was desirable that all moulding sands should first be subjected to mechanical separation, and then, instead of making a bulk chemical analysis, it should be the aim to find the constitution of each size or grade of grain.

Naturally, that led to the question of the bond. When he began working on moulding sands he came to the conclusion that the essential bond material was clay, because one could work with very clayey sand quite successfully, and in America, and in this country, too, fire-clay wash was used as a bond. More recently he had come to the conclusion that the other material, the iron-oxide in its hydrous or anhydrous form, really played the more important part. The analyses of moulding sands, which would be published shortly by the Ministry, indicated that the amount of water present over the mere drying temperature of 100 deg. C., or thereabouts, even allowing for the little hydroscopic water which could not be driven off, was far more than enough to satisfy all that was required by the clay material present, and in all the most successful sands for green-sand work, such as those imported from France, Belgium, and one recently discovered in South Africa, a very large percentage of iron was always present. The nearest British equivalent to these imported sands was that found near St. Erth in Cornwall. The whole question was also wrapped up with the general one of bonds of the colloid form, for iron-oxide, like clay, gelatine, glue, gum, was a colloid. The use of colloid bonds in steel moulding sands and for other purposes had long been known.

The whole question of steel moulding, he thought, resolved itself into getting a bond which combined the necessary chemical analysis with the ability to persist in the collodial condition, if not up to the temperature at which cast steel was cast, at least up to a certain point, and thus maintaining a firm structure. On that account he thought that the chemical constitution of the bond must be the dominating factor. At the same time, he quite resognised that until they had separated out all the various grades and measured the actual conductivity and other properties of each material present, one must not be too dogmatic; but he was quite clear that chemical action played a really imporant part. When burning on occurred the silica went over into a glassy form. In that condition glass had a greater affinity for the steel than for the other silica grains in the mould. But when manganese silicate hung on to the mould and not on to the steel, the case was different. It might be that similar iron compounds were formed at these high temperatures. They had not yet enough analyses or work done on mixed moulding sands, which had proved successful under well specified conditions, to go into the whole question thoroughly. In opening the discussion he had rather endeavoured to bring out certain of the points which puzzled the scientific worker, in the hope that practical foundrymen would show them a lead, which they could hope to follow when seeking the nearest home substitutes for some of the very successful materials which hitherto had been imported from abroad. If practical users of moulding sands would explain their difficulties and say what their requirements really were, instead of arguing and continuing to hold absolutely diverse opinions as to what they really did want, geologists might perhaps be able to help them.

Mr. C. K. Everitt said it was very interesting to find that two such eminent scientific investigators should have arrived at very much the same conclusion, which was that what was wanted in a moulding sand was some material which would glaze, but which, by glazing, would not make an aggregate so strong as to offer too much opposition to the shrinking of the casting, and which also would not prevent the passage of the gases. It was, he thought, rather a problem to discover such a material; but he had no doubt that they would all learn a great deal from investigations such as these and other gentlemen similarly situated were carrying on. The sand that was formerly obtained from France and Belgium certainly had those properties of taking on a slight glaze and peeling away from the castings very freely. As far as his own experience had gone with artificial mixtures, they generally found that Nature did these things better, but if an artificial mixture had to be used it seemed to him that the best results were got when some organic substance was used to stick the particles together. He thought that came about by the circumstances that these organic substances, by the intense heat generated from the cooling casting, were expelled altogether, and whilst they did not give the glaze which was desired, they did give a very refractory substance, and a substance which, when those organic materials had been expelled from between the particles of sand close up to the mould, took on the crumbling condition which was so necessary in steel casting work.

Dr. Hatfield remarked that when Professor Fearnsides spoke of the great increase in strength which the addition of water gave to the sand, it called to his mind the snap flask, just a wooden frame which the moulder removed after the mould was built up, leaving only the sand unsupported, with a heavy weight upon upon the top of it. The success of that system, he thought, must appear very strange to some men in the foundry, because, as the mould became dry one would expect it to collapse under the weight. That, of course, was a practical instance of the part played by surface tension.

Mr. Brown referred to what Professor Fearnsides had said with regard to the changes which took place in the silica which came into contact with hot steel castings. Some of them had had a lot of experience in steel casting, and they knew that at a certain temperature they were able to take that silica sand clean away, but though at a red heat it could not be done, when cooled it would come away of itself. It was most interesting to know what changes took place.

British Foundrymen's Association.

SCOTTISH BRANCH.

At a meeting of Scottish Branch on March 2, Mr. Matthew Riddell in the chair, Mr. J. Donaldson, B.Sc., read a Paper on "Special Irons." The lecturer at the outset stated that he proposed to consider the influence of certain elements on cast iron other than silicon, phosphorus, sulphur, and manganese. The elements in question were vanadium, titanium, aluminium and nickel. A great deal of research work had been directed to the influence of these elements on steel, but the investigations which had been made regarding their effect on cast iron had been of a very limited character. Of the four elements mentioned the influence of vanadium was perhaps the most important to foundrymen. Vanadium increased the tensile, transverse, and compressive strength of cast iron, and this influence was brought about through the effect which it had on the carbon in assisting to retain it in the combined form. A microscopical examination of the structure of an iron containing vanadium exhibited a very fine grain, showing the carbon evenly distributed, and the metal free from hard spots.

Vanadised iron had proved specially suitable for parts of internal-combustion engines subjected to heat and internal pressures. The wearing properties of an iron were also greatly increased by the addition of vanadium. The introduction of vanadium was best accomplished by first forming a ferro-vanadium alloy, grinding it to a powder, and introducing it at the spout of the cupola so as to pass with the metal into the ladle.

The lecturer stated that for ordinary work 0.15 per cent. of vanadium was considered ample. Tests had been made showing an increase of 3½ tons on the tensile strength of an iron with an addition of 0.2 per cent. of vanadium; the particular test referred to raised the tensile strength from 10.71 tons to 14.28 tons. Another iron had its tensile strength raised from 11.6 tons to 16.5 tons, the percentage of vanadium in this experiment being 0.15. The effect of vanadium on the transverse and compressive strength of an iron was equally great; experiments had been made showing an iron which failed in a transverse test at 1,300 lbs., but when the same iron had been vanadised with 0.125 per cent. of vanadium, it attained a transverse strength of 2,200 lbs. In another quality of iron the transverse strength was raised from 2,500 lbs. to 3,400 lbs., the deflection being the same in both experiments, with and without the vanadium. Several examples were quoted showing the effect of vanadium in increasing the compressive strength of cast iron, one experiment showing an increase from 60 tons to 70 tons per sq. in., the proportion of vanadium introduced in this particular case being 0.18 per cent.

Titanium was introduced to cast iron in a similar manner to vanadium, and so far experiments had shown no advantage gained by having more than 0.15 per cent. of titanium present in the iron. The virtues claimed for titanium were that it improved the transverse and compressive qualities of cast iron. However, the experimental work on titanium applied to cast iron had been very small, and until further research work had been carried out the advantages or disadvantages of titanium as applied to cast iron must be held in abeyance.

The general effect of adding aluminium to cast iron was very similar to silicon because of its influence on the separation of the carbon. The addition of nickel had an effect of a similar character. The whole question of special elements in cast iron was a subject of intense interest to foundrymen, especially at the present time, when the demand for the favoured brands in some cases exceeded the supply.

Institute of Metals.

At the meeting of the Institute of Metals held on March 13 and 14, several Papers dealing with non-ferrous metals were submitted. According to the report of the Council the more general employment of scientific metallurgists in works engaged directly and indirectly in the production of munitions of war has aroused the interest of technical and scientific experts and of manufacturers in the work of the Institute, and this has led to a very large increase in the applications for membership. The total number of members on the roll of the Institute on December 31 was 888, of which four were honorary, 860 ordinary, and 24 student members, showing the substantial net increase of over 34 per cent. during the year.

The work of the Corrosion Research Committee is still being conducted with the assistance of funds contributed by the Department of Scientific and Industrial Research, various associations, firms, and by the Institute. The Government grant-in-aid has been increased during the year from £650 to £1,000 per annum, the latter rate applying as from October 1, 1917. A further Government grant-in-aid of £450 has been received, together with a grant of a similar amount from the British Electrical and Allied Manufacturers' Association. The aggregate sum of £900 has been placed at the disposal of the Institute in order to carry out an investigation into the cause, or causes, of the corrosion of condenser tubes on land by fresh water; the research is being carried out on lines parallel to those adopted in the case of the existing salt-water research. For the purpose of conducting this latest investigation, a Fresh-Water Corrosion Research Committee was appointed as a sub-committee of the Corrosion Research Committee.

The accounts presented for the past financial year by the Honorary Treasurer show an excess of receipts of £698 over expenditure, as against an average excess of £156 in the four preceding years.

Papers presented at the meeting and the report of discussions thereon will be published in our next issue.

CONTROL OF TIN.—With reference to the addition of tin to regulation 30b of the Defence of the Realm Act, the following particulars are given for general information:—(1) The regulations do not apply to purchases made outside the United Kingdom until the metal reaches this country. (2) Export orders and sales to Allied or Neutral Countries through authorised channels are deemed to be consumers' orders. (3) It is permissible for merchants, warehousemen and retailers to replace metals sold after December 21, 1917, by the purchase of an equivalent quantity of the same metal, but not more, although the metal so purchased may not be the metal actually delivered against the sale. (4) Consumers may buy for their consumption only.

Replies to Queries.

Brass Melting.

In the February issue of the FOUNDRY TRADES JOURNAL the query is asked, "How many coke-fired furnaces in ordinary usage are worked by one melter? Does he fetch and prepare his own coke, clear ashes, lift up crucibles, clay up furnaces, etc.? Also how many 80-lb. or 100-lb. crucibles of gun-metal should be melted in six furnaces for a day of 9½ hours, by a man with a boy as helper for coke and ashes."

To answer these queries, though on the surface they seem very direct, necessitates a knowledge of the conditions of working, even assuming that the furnaces themselves are as satisfactory in their working as is possible to obtain them.

First, there is the individual himself. He must be selected with extreme care, and in addition to being strong, must have brains and know how to use them.

Second, are the conditions the man works under. Everyone with experience will admit that at its best the job is a laborious and at times an unpleasant one, and the standard of what an individual can do will be affected by conditions, such as ventilation, protection from draughts, loftiness of foundry, etc. The distance he would have to fetch his materials, and how far the ashes would have to be taken, must also be considered. If the materials be close at hand, the obtaining of them would be a small matter; but if at a good distance away, it may be an impossibility for him to carry out his duties in a proper manner. The same also applying to the carrying away of the ashes.

The wage paid, which can be definitely stated, is generally the deciding factor. If the man is remunerated in proportion to his occupation, he will answer the questions asked by the work he will do; that is, if the right type of individual has been selected; and when it is considered that the work of perhaps a dozen or more highly-skilled, highly-paid men depends upon how he performs his duties, it should prove that he *must* be above the standard of an ordinary labourer.

Therefore, the problem of making comparisons with what is carried out at other establishments depends upon the conditions applying, and it would not do justice to anyone concerned if these were not compared along with the results obtained.

At the works the writer is connected with, under very good conditions, one man has charge of four furnaces of 100-lb. capacity, melting gunmetal every heat. He performs all the duties mentioned, with the exception of bringing coke and taking away ashes, although he does throw the ashes up out of the pit, these duties being carried out by a labourer, whose other duties are not in connection with the melting. He is allowed two hours extra before breakfast for the patching up of the furnaces, so that he can start up when the moulders come in at 8.30 a.m. to commence work, this being starting time for that day. Other days he works the same time as the moulders.

As to the time it should take to melt a given amount of metal, this should be not from the time it is introduced into the furnace until the time it is taken out, but the time from the lifting of one pot to the time of lifting out its successor. Under these conditions, and assuming that everything is in order, we consider a daily average of three hours per pot good working; thus in 9½ hours we should expect three melts per furnace. It may help our friend to know that in some establishments a bonus of a certain figure is given for each crucible lifted; but our practice is to give the man a bonus on output, as the other method tends to tempt some individuals to lift up crucibles that are not full.—A. H.

Blow Holes in Castings Off Chills.

This is a problem that occurs to all foundrymen at times if they are called upon to use chills or denseners; and in no case does the problem present itself more vividly than when wrought-iron chills are used. From personal experience and experiments, the writer does not consider the trouble is from gas arising out of the chill. The querist, "B. H.," says that he warms the wrought-iron pins to about 500 or 600 deg. F. before introducing them, and this no doubt is the cause of his trouble, as the heat will attract the moisture from the sand, which will adhere to the surface in very minute particles. This feature takes place in a very short period, as he will find if he will take off the cope, say, five minutes after introducing the chill.

This feature presents itself on both cast and wrought chills, but as wrought-iron ones are generally of smoother surfaces than cast, the particles are much smaller, and do not tend to flow away with the stream of metal. Hence, they do not develop until after the mould is filled, this being the reason they do not get away very far from the chill, as "B. H." mentions.

The fact that it is moisture from the mould can readily be proved by drying a mould and noticing that the casting will be a good one. That has been the writer's experience. Warming the chill thus only encourages the feature, and our practice is to use cold chills, but *dry* ones, and keep the moulding sand on the dry side. These chills are every day put in soon after six o'cock a.m. and onwards, up to between three or four o'clock in the afternoon, when we commence casting, this taking place day after day.

If at any time we desire to use the sand on the damp side, we coat the chills thinly with a paste made of linseed oil and plumbago, which is dried on with heat, but the chills are allowed to go cold before using.

The flowing back of metal I have also had experience of, but have generally found that it was caused by hard ramming or wet sand.

It is generally admitted that new chills give least trouble in so far as the chilling properties are concerned, owing to old ones becoming burnt; but we have chills in use that have been used upwards of 100 times that do not give any trouble either by blowing or not chilling, this being due no doubt to the fact that we make a practice of chilling the chill itself, and in no case do we use a wrought-iron one. The metal used is as follows:—20 per cent. Staveley, 4; 10 per cent. white (Fenton); 70 per cent. scrap (half of which is shop returns). This gives a metal that will machine where not chilled, but will also give the chilling result where it is desired.—A. H.

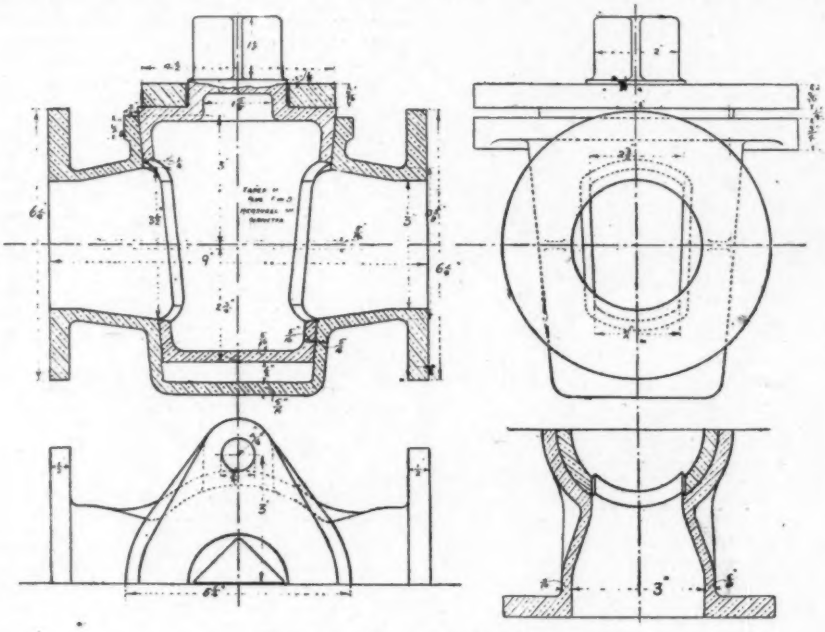
AUSTRALIAN STEEL FOUNDRIES.—At present there are in Australia from thirty to forty crucible steel foundries, fifteen of which are regularly producing steel castings. There are seven side-blown converter plants, two of which are Government plants. One Stock converter plant is already in operation, and two or three others are being constructed.

Pattern-Making and Foundry Work in Technical Schools.

By Chas. A. Otto.

A course of pattern-making and foundry work, given in conjunction with each other, is especially valuable in connection with the training of engineering students in technical schools, because of the character of problems which it introduces. Usually these are considered instructive because of the manual training exercises connected with such a course, whereas that is only incidental to the more important results obtained. It is more valuable to impress upon the student, as early as possible in his work, the desirability of a careful consideration of the many other factors involved in the majority of workshop operations besides those incidental to the work of construction.

As an illustration of this feature of such a course consider some of the problems presented with the accompanying sketch of a simple straight-through cock.



Sketch of Straight-through Cock.

It is interesting and of educational value to occasionally provide drawings having slight inaccuracies, as the quickness displayed by the students in discovering an error gives evidence of their knowledge of the principles of machine drawing. It assists in developing their capacity for reading drawings accurately.

The first problem the student is requested to answer requires foresight, the ability to visualise his work and devise the method of construction when one set of castings is required. This initiative is encouraged in determining how such patterns will differ from those required to provide a number of sets of castings and the modifications desirable for manufacturing a much larger number.

A knowledge of operations in the foundry becomes equally as essential as that required in constructing the pattern work. He must consider whether it is more economical to save the time of the pattern-maker and expend a little more time in the foundry or to increase the amount of work in the pattern shop, so that the time occupied in the foundry will be reduced. A knowledge of machine moulding is necessary so that provision may be made when large numbers of castings are required.

The second problem necessitates a knowledge of the timbers most suitable under the varying conditions, to determine the capacity of woods in resisting the effects of moisture and rough usage in the foundry. Dimensioned sketches will indicate clearly the allowances for machining and contraction, and will tend to emphasise the need of varying the allowances for different classes of work.

The calculation of the weight of each unfinished casting in the set encourages the practical application of mathematics, and by making a suitable allowance for gates and risers, the student will become acquainted with the methods adopted in calculating the amount of metal required to cast a given job.

Students are, as a rule, very much interested in moulding processes, and they show remarkable aptitude during the course of practical instruction. To discover the extent by which they profit from such instruction it is advantageous to request a vertical section through each of the moulds, representing them as they would be preparatory to pouring the molten metal.

By means of these problems the desirability of having certain mixtures of metals for different classes of work can be impressed upon them more easily, as, being in the nature of test questions given periodically, they endeavour to anticipate

such problems by closer attention to their work, inquiries of their teacher, or from text books on the subject. Moreover, this method introduces them, early in their training, to workshop economy and management, and tends to make them more observant and critical of castings generally. They examine castings with greater interest, looking for signs of fin which may determine the joints used in the moulds, or for indications of chaplets having been used in supporting cores.

As the sketches made in solving these problems should have proper proportions given to the parts of the arrangement sketched, an opportunity is given to correct any wrong ideas the students may have regarding the details of construction, such as the jointing of patterns and their moulds, gates, risers, venting, etc. There is also an opportunity to introduce to them a greater variety of work than they would have the time to consider in the usual manual course. Examples of a larger class of work could be chosen, involving the use of skeleton patterns, strickling or sweeping boards for cylindrical work, etc., making the problems more complex when considering the work in the foundry.

Questions accompanying sketch.—The drawing shows various views of a straight-through cock. Make sketches showing the pattern work required to be furnished to the moulder when (*a*) one set of castings is required, (*b*) a dozen sets required, and (*c*) for 200 sets of castings. Dimension the sketches to include all necessary allowances, and indicate the material desirable in the construction of the work.

Estimate the weight of each unfinished casting in the set, and give an analysis of the metal required.

Sketch a vertical section through each of the moulds for those which would be prepared if only one set were required. Show the moulds ready to receive the molten metal, and give a short description of the method of procedure, introducing the names of the materials used in their preparation. Indicate joints in the mould by thick lines.

"F.T.J." Bookshelf.

Refractory Materials: Their Manufacture and Uses.—By ALFRED B. SEARLE.—London: Charles Griffin & Company, Limited, Exeter Street, Strand, W.C.2. (15s. net.)

The purpose of this treatise is to summarise in a convenient form our knowledge about the chief materials and products used in the construction of furnaces, &c., and to describe the manufacture and properties of firebricks, retorts, crucibles, &c., used in the metallurgical, engineering, chemical and other industries. The intention is to supply the user of refractory materials with information on their main properties, whilst the manufacturer may also find many points of interest to him. It is claimed that no other book published in this country is devoted solely to this important subject, which appears to be correct, as F. T. Havard's treatise is on "Refractories and Furnaces" (1912), and, moreover, is, perhaps, more of an American publication. The author of the present volume is Mr. Alfred B. Searle, the well-known consulting expert on clays and clay products, and the author of several treatises dealing with one or another of such cognate subjects as clays and clay products, kilns, and kiln building, etc. His first chapter deals with the raw materials (acid, highly silicious, neutral, basic, and other refractories), whilst the second is devoted to a description of the manufacture of firebricks from clay. In the concluding paragraph of this chapter we are told that after a lengthy experience of British and German firebrick works the author became convinced that if British makers were to exercise the same skill and care, combined with equal scientific facilities as those exercised and to be found in German works, our products would be greatly superior to anything made in Germany. The great improvements made during the past few years by several British makers is—he thinks—an interesting confirmation of this opinion. It should be noted with regard to these statements that the author's MS. was completed and delivered to the publishers in the early part of 1914, but the outbreak of war, and, later, a fire at the printers, have considerably delayed its publication. In the preface, however (dated February, 1917), we are again told that it is a curious fact that with raw materials inferior to those commonly used in Great Britain, the Belgian, German, and Austrian makers have produced in the past goods which are more accurate in shape, less affected by severe conditions of use, and are generally recognised as being of higher quality than those made in this country. Moreover, foreign makers have been willing to guarantee results to an extent which most British makers have considered impracticable. Chapter III. deals with silica firebricks and their manufacture, and is followed by other five on almost every other kind of refractory brick in use. Other nine chapters deal with a variety of other materials, such as blocks, slabs, hollow ware, potter's saggers, muffles, crucibles, gas retorts, &c., and with refractory mortars and cements. A chapter of great practical utility finally discusses the selection and application of refractory materials for specific purposes, such as blast furnaces, coke ovens, gas producers, steel furnaces, etc., with a sub-section on tamped linings for furnaces, embodying an appendix on testing refractory articles. This last chapter discusses (under separate headings, arranged in alphabetical order, from air furnaces to steel furnaces) what kind of refractory material would probably be the most suitable for the given purpose, the selection being guided in each case by an examination of the conditions which are likely to prevail in the furnace, or coke oven, or kiln—as the case may be—under consideration. The extracts at the end of the book from recent specifications issued by various public bodies or institutions, or industrial firms will be found of special interest and great help. As regards details, we have only space left to refer to the author's verdict about single kilns *v.* tunnel and continuous kilns. For refractory goods of the very highest qualities, and requiring to be burned at the highest temperatures obtainable industrially, it is essential, in the author's opinion, to use single gas-fired kilns of small size; but may we point out to him that for burning high-grade clay wares, tunnel-kilns have been in use in Germany (at Altwasser) for over a dozen years, and in the United States for at least ten years (at Schenectady and Keasby). The author's statement that in tunnel-kilns the fires are "at the centre" of a long tunnel is evidently a slip, as the firing zone is almost always nearer to the discharge end than to the charging end.

"COOPERITE": A NEW HIGH-SPEED ALLOY.—A new use of "zirkite" has been developed within the last few months; namely, as a source of metallic zirconium for the manufacture of a new alloy of nickel-zirconium, known as "cooperite." The new alloy has a bright, silvery lustre and a specific gravity much lower than other alloys used for high-speed work. "Cooperite" contains no carbon or iron, and, consequently, is not a steel. Its melting point is only about 1,150 deg. C., and owing to the fact that the alloy remains in liquid state for a considerable period before solidifying, difficult castings can be made with ease. No heat treatment is said to be required, the hardness being varied by changing the proportion of the constituents. Cutting tools have been produced with a harness of 250 up to 500 Brinell, the latter still retaining sufficient toughness to withstand heavy roughing cuts.

Fluorspar.

Its Crystallisations and Value.

By James Scott.

The practical value of fluorspar in foundry for smelting purposes is well understood, but it is probable that the structural and chemical phases of the substance have not received very close attention. Fluorpar is by many considered indispensable for the manufacture of basic open-hearth steel. It is also of extreme service in other work, such as blast furnace working. In connection with the reduction of the ores of antimony, copper, lead, and some other metals, it has been proved to be of much value.

The value of fluorspar lies chiefly in the fact that it liquefies to a notable thinness the refractory mineral gangue which accompanies the ores, besides the limestone, etc., which is added to the mass. While it has, apparently, no striking effect on the basic oxides, such as those of lime, its action relative to the sulphates of lime and barium are very satisfactory. It also serves as a desulphuriser and dephosphoriser, carrying the excess of these two elements away in the slag. The silica, too, fuses well with it.

Fluorspar is known also as fluorite and calcium fluoride. It is a compound of lime and fluorine, the latter being a pale yellow gas belonging to the group of halogens, the remaining members of which are bromine, chlorine, and iodine.

Fluorspar is found either as transparent white masses, or translucent and tinted with almost every colour of the rainbow. The tints can be discharged by means of heat, and are believed to be due to the presence of impurities originating from volatile organic products of the hydrocarbon series.

The best kind for foundry practice is the white, and the crystals to be procured from this comprise a most interesting and attractive set. Besides the crystalline varieties, nodular, or large pieces, compact and somewhat granular, and earthy states of fluorspar, occur in some countries, and may also be white or banded with colours. It has also been known, briefly, as fluor, or else fluate of lime. Its formula is CaF_2—that is, calcium (lime) and fluorine.

By treatment with concentrated sulphuric acid and the application of gentle heat upon fluorspar, this, when condensed, becomes hydrofluoric acid, the latter yields hydrofluoric vapour or gas; and remarkable for its power of etching or consuming glass and other silicates. It is dangerous to prepare this acid, unless suitable apparatus is provided with that object in view, owing to the suffocating and poisonous nature of the copious fumes evolved by the chemical reactions.

The primitive or fundamental crystal of fluorspar is regarded as either the cube or the octahedron, both of which are, however, closely associated together in the same crystallographic system. But so amenable to modification are the components of this mineral that an immense variety of forms is discoverable. Some of the most distinctive of these are shown in Fig. 1. All are derived simply from the main type by suppression, during "growth," or formation, of certain planes or corners; or the superimposing of successive thin layers in special directions.

The larger crystals are very well shaped on the surfaces of fluorspar as it is mined, and can be plainly seen by means of a low-power or reading lens. Most of those which I have viewed are cubical, the objects being very curiously arranged.

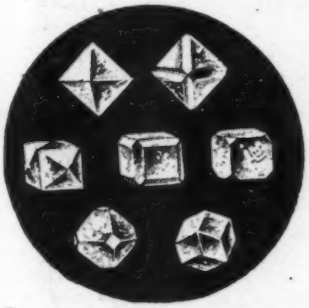


Fig. 1.— Selection of very Small Perfect Crystals of Fluorspar, Magnified. All are Variations of the Cube or Octahedron.

Fig. 2.—About 1-24 inch of Surface Layer of Fluorspar. Consists of Conglomerate Crystals, Perfect and Imperfect.

Fig. 3.—A Selection of Symmetrical Particles of Fluorspar, obtained by Crushing a Small Piece; Magnified from 1-24 inch.

In Fig. 2 is shown a portion of the unbroken surface and immediate underparts of fluorspar. Here we see, intermingled, a heap of cubes, octahedra, and other forms, some comparatively small and the remainder fairly large. Many blend peculiarly into their fellows.

Fluorspar, as the worker will be aware, is easily cleaved; but close inspection has to be made in order to discern the condition of the fractures. In well-shaped, neatly struck lumps of the material the exposed crystals exhibit very clear and sharp planes appertaining to tetrahedra, octahedra, and similar figures, derived from the original ones. Irregular or severe splitting will usually result in so finely splintered a texture that the surfaces will present an opaque milkiness. Curved lines or cracks densely permeate the crystals at such times.

On magnifying the dust obtained by pulverising fluorspar, many exact and symmetrical particles can be secured. On flattening small pieces of the broken crystals between two glass slides there appear among the numerous glittering, gritty spicules a fairly large number of the objects shown in Fig. 3, the majority of them consisting of laminæ split off from the larger crystals along the

lines where they were in the first instance blended together.

Minute drops of fluid, containing movable bubbles, are often seen locked up in cavities within fluorspar crystals. When the mineral is crushed on glass the latter generally gets splashed with released exudations, but the amount is not at all conspicuous. In some samples of fluorspar we can detect little enclosures of dark or light hued matter, which gives a turbidity to the whole mass.

If powdered fluorspar is thrown on to a coal fire in a dark room it will phosphoresce remarkably. Most kinds of fluorspar fluoresce, or "bloom," very strongly when exposed to the violet and ultra-violet rays of the spectrum; and it is very obvious that the name of the compound was founded on this extraordinary behaviour.

Study of fluorspar in the preceding manner enables us to understand some of the reasons for its actions. Heat and sulphuric acid, for example, decompose it, and yield a silicate-consuming gas or fluid. Oxidation of the sulphur in the ore no doubt helps in such a process to acidify the fluorspar, the products of which, by attacking the silica, causes the extra limpidity noticeable to the practical man.

A High-Temperature Electric Resistance Furnace.*

By Walter Rosenhain, D.Sc., and E. A. Coad-Pryor (National Physical Laboratory).

All the well-known types of high-temperature electric resistance furnaces, in which the resistor consists either of granulated carbon, of a simple carbon tube, or of a graphite spiral, possess certain serious disadvantages which lessen their utility and convenience in use. It is believed that the type of furnace here described, although still relying upon carbon or graphite for the resistor, overcomes all disadvantages, although it does not entirely eliminate the necessity of keeping the resistor in a neutral atmosphere and the difficulty of avoiding the presence of carbon in the atmosphere of the furnace. The latter difficulty can, however, be overcome to a sufficient extent for many purposes. The principle on which the construction of the present furnace is based is the utilisation, not of the ohmic resistance of the graphite, but of the resistance which exists wherever graphite surfaces are placed in contact.

The general construction of a typical furnace, having rings of 7-in. bore, is shown in sectional elevation in Fig. 1. There are 60 graphite rings in a vertical height of 12 in. At the bottom these rest on a turned graphite block (*b*), fitting the rings and forming a solid bottom for the furnace chamber. Through the centre of this block passes the iron tube (*c*), to serve as a gas outlet. Above this, resting on the centre of the block, stands a perforated graphite tube (*d*), forming the support for a crucible. The perforations allow a free flow of gas from the furnace-chamber to the outlet tube. The graphite block (*b*) fits, externally, into the water-cooled metal electrode (*e*), consisting of a brass casting cast around a coil of iron pipes seen in section in the figure. The upper electrode is similar in construction. In order to secure good electrical contact between the brass surface of the electrode and the graphite block or tube fitting into it, the surface of the graphite was in some cases first coated with copper (using the Schoop metal spraying process), subsequently "sweating" the graphite thus prepared into the brass socket. More recently electrodes of this type have been made of an aluminium alloy, in which case soldering became inconvenient, and consequently a plain conical fit, carefully machined, has been tried and found quite satisfactory. The metal electrode rests on the steel base-plate of the furnace, (*f*) being electrically insulated from it by a layer of uralite (*g*), fibre washers (*h*) being used to ensure insulation at the points where the cable sockets (*i*) pass through the base-plate. Cables from the transformer are attached to these cable sockets at both top and bottom of the furnace. The construction at the top is similar, with only such modifications as are necessary in order to allow

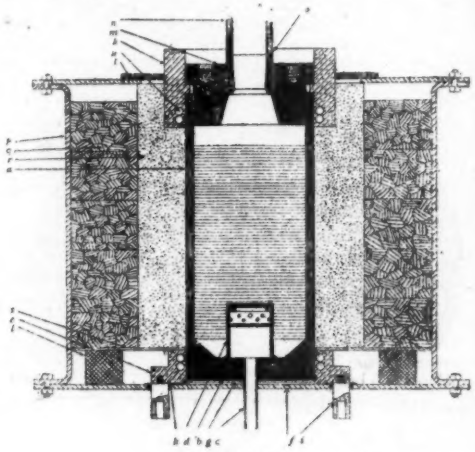


Fig. 1.

the furnace to be completely opened for ready access to the interior during working. In place of the solid graphite block used at the bottom, a graphite tube, of the same diameter as the rings, is used to make contact with the top ring. This tube (*j*) in turn fits into the upper water-cooled electrode (*k*), which is provided with a flange in order to transfer its weight to the graphite tube. This electrode is machined on the outside and passes as a good fit through a plate of aluminium alloy (*l*), which is electrically insulated from, but firmly attached to, the top cover-plate of the furnace-casing. This arrangement allows the electrode to expand freely through the aluminium plate, the joint being, however, kept as gas-tight as possible. The top of the furnace chamber or tube is closed by another solid block of graphite (*m*), which lies upon the flange of the upper electrode. This block can be easily removed by a suitable handle. For use while the furnace is at work a smaller opening is provided by cutting a hole about 3 in. in diameter in the centre of the graphite block. The lower half of this hole is coned outward and downward to allow of a wider field of view from above; while the upper half of the hole is slightly tapered upward, into which taper fits the slightly coned end of a graphite tube (*n*) of 2-in. bore. This tube is for convenience

* Abstract of Paper read, February 14, before the Faraday Society.

made in two parts, the upper fitting on to the lower at a stepped joint (*o*). The top of the tube has a cap with a wide mica inspection window. By closing a graphite slide, the mica window can be bodily removed, without admitting air into the furnace. This is particularly important where observations with an optical pyrometer are to be made. Immediately below the shutter or slide is the inlet tube—of silica—by which nitrogen gas is supplied to the furnace. The graphite resistor and parts of the electrodes are enclosed in a substantial steel case in order to render the whole apparatus as gas-tight as possible. The barrel of the case (*p*) consists of a steel tube with a flange at top and bottom, to which the cover-plates are bolted. In the furnace described this steel tube is 18 in. high and 22 in. in external diameter. The steel casing is lined with magnesia blocks (*q*), for thermal insulation. Between these blocks and the graphite rings is a layer (*r*), about 3 in. thick, of vegetable black (a form of light, finely divided carbon), which serves as additional heat insulation and also serves to surround the outside of the graphite rings with an atmosphere rich in carbon.

With regard to the general dimensions of the furnace described above, it may be remarked that while wholly satisfactory for temperatures up to 1,500 deg. C., the ratio of length to diameter is not adequate for higher temperatures. In the case of a furnace having rings of 9-in. bore an internal height of 28 in. has been adopted. The temperature which can be obtained in a furnace of the type described is, within the limits of endurance of the graphite itself, limited only by the power available and the adequate cooling of the ends. A furnace 2¾-in. bore attained a temperature of 1,500 deg. C. with a consumption of 8 k.v.a. in about 30 minutes, and 1,700 deg. C. with a consumption of 10 k.v.a., the actual current in the latter case being about 400 amps. (alternating current) with about 25 volts. If it were desired to heat a plain carbon-tube resistance furnace of the same dimensions to the same temperature, a current of 1,500 amps. would be required. In a furnace having an internal diameter of 3¼ in., pure iron can be melted with a power consumption of 11 k.v.a., taking a current of 550 amps. In a larger furnace having an internal diameter of 7 in., corresponding to the one described in detail above, a temperature of 1,650 deg. C. was attained with a power consumption of 23 k.v.a. (2,000 amps.). This considerably lower efficiency was due to unduly small ratio of length to diameter.

The Scope of a Laboratory.

In a recent Paper read by MR. F. C. H. LANTSBERRY before the Birmingham Section of the Institute of Metals on "The Scope of a Laboratory," the author introduced his subject by stating that the future industrial prosperity and commercial supremacy of the whole Empire depended largely on the application of science to industry, and yet the view had been expressed that it was the patriotic thing nowadays to employ Doctors of Science and "those sort of people," but that when the war was over we should be able to do without them. Happily such a view did not exist in the metallurgical and engineering industries, in which undoubtedly the laboratory had come to stay, because it had proved its value.

The differences between the laboratory needed for the chemical works and for the engineering establishment differed only in matters of detail, which might be left to be determined by circumstances. In any case, the laboratory should include a technical library, and the staff should have access to current literature in all languages they were capable of reading. As to its functions, the laboratory should be held responsible for the quality of the raw material and materials incidental to manufacture coming into the works, and also of the finished product. The laboratory should control quality, and the purchasing department should control prices after quality had been settled, the two departments working in closest co-operation. The laboratory could be of immense practical use in making a study of the effects of variation in composition and physical condition upon the costs of production. For that purpose a knowledge of prices was absolutely essential. The laboratory should also carry out research with the objects of discovering new products and processes and of introducing improvements into existing ones, a function likely to appeal to the trained scientific mind.

In the course of a lengthy discussion several speakers criticised the extensive field of control sketched out for the laboratory. PROFESSOR TURNER, replying to a demand that the University should take up specific lines of research for special industries, said that could only be done when it happened to furnish a useful field for young students requiring practical work.

Deaths.

MR. J. GLOVER, brassfounder, Greenside, Ayr, died recently at the age of 89 years.

MR. JOHN GLOVER, brassfounder, of Bridgeton, Glasgow, has died in his 89th year.

MR. J. M. HEWITT, of Hale, Cheshire, consulting engineer, died recently, as the result of an accident.

MR. J. CORT, of Jos. Cort, Ltd., metal merchants, Canterbury Street, Blackburn, died recently at the age of 77 years.

THE death is reported of Mr. E. Mercer, of Edward Mercer, Limited, Hollins Ironworks, Oldham, at the age of 61 years.

THE death took place recently of Mr. J. Carter, managing director of Carter Brothers (Rochdale), Limited, engineers.

MR. T. H. HAIGH, technical manager at the Bryan Donkin Company's engineering works, Chesterfield, died recently at the age of 43 years.

THE death is announced of Mr. H. Radnall, secretary to Thomas Bolton & Sons, Ltd., copper manufacturers, of Widnes, Birmingham, and London.

THE death is announced of Mr. R. Marston, joint-managing director of John Marston, Limited, Paul Street Works, Wolverhampton, at the age of 45 years.

MR. T. BRADLEY, of Beechurst, Beeches Road, West Bromwich, a partner in the firm of Field & Bradley, iron merchants, Swan Lane, West Bromwich, died on March 7.

MR. J. KENNEDY, founder and chairman of both the Glengall Iron Works, Limited, and the British Arc Welding Company, Limited, died recently at the age of 78 years.

THE death is announced in the German papers of Herr Johannes Klein, founder of the Maschinen und Armaturénfabrik, formerly Klein, Schanzlin & Becker, of Frankenthal, Pfalz, Germany.

THE death occurred on March 17, at his residence, Somerset Grange, Edgbaston, of Mr. Walter Smith Bradley, of Bradley & Company, Limited, hollow-ware manufacturers, Bilston. Mr. Bradley, who was in his 64th year, retired from active interest in the business of his firm about six months ago.

M. EUGENE SCHNEIDER, the president-elect of the Iron and Steel Institute, has lost his eldest son, Second-Lieutenant Henri-Paul Schneider, in the war. His

machine was shot down while attacking a fleet of German aeroplanes. After landing close to the firing-line he was rescued, but died of his wounds a few hours later.

MR. T. ALEXANDER, J.P., of Harbour View, South Shields, died in London, Febraury 25, after a short illness. Mr. Alexander, who was 56 years of age, was managing director of the Tyne Dock Engineering Company, Limited, and a director of the Deptford Dry Docks Company, Limited, and the Ocean Dry Docks Company, Limited.

SIR MYLES FENTON, who has died at Redstone Hall, Redhill, in his 88th year, began work on the railway at Kendal at the age of 15. After service on the East Lancashire, Eastern Counties, and London & South-Western, he became secretary of the East Lancashire Railway in 1856, general manager of the Metropolitain in 1863, and of the South-Eastern in 1880, and consulting director of the South-Eastern and Chatham in 1896.

LIEUT.-COL. G. A. W. LAMOND, R.E., whose death is announced, was trained as a civil engineer in the offices of Messrs. Foremans & McCall. Later he was employed for many years with the firm of Sir John Aird & Company. On the outbreak of war he saw service in France and was rapidly promoted. About 18 months ago he went to another front with the rank of lieutenant-colonel, and was on the staff there as an assistant director of Inland Water Transport. He was invalided to Colombo, and died there on February 25, aged 39.

THE death has occurred of Mr. Samuel Lloyd, of Birmingham, who early in life took part in the management of the ironworks at Wednesbury, then carried on under the name of Lloyds, Fosters & Company. Mr. Lloyd's entrance into the firm, which in later years became the Patent Shaft and Axletree Company, was abundantly justified by the improvements in the methods of production which his knowledge enabled him to introduce. In 1859, in conjunction with his cousin, he founded the well-known tube firm of Lloyd & Lloyd, and he remained a director until the business was extended by amalgamation some years ago, under the title of Stewarts & Lloyds, Limited. He also took a part in establishing the business in Northamptonshire known as Lloyd's Ironstone Company, of which he was the chairman for many years.

We regret to announce the death of Mr. Greville Jones, the general works' manager at Port Clarence, Middlesbrough, of Bell Bros., Limited, which firm is allied with Dorman, Long & Comany, Limited. The deceased gentleman, who died on March 6, at his residence, Homewood, Linthorpe, Middlesbrough, at the age of 54 years, from pneumonia, was born and educated in South Wales. He received his metallurgical and technical training at the Rhymney Iron Company's works (these works being then under the management of the late Mr. David Evans, who was for a number of years general manager for Bolckow, Vaughan & Company, Limited.). While employed there Mr. Jones attended evening classes, where he studied theoretical and practical chemistry, metallurgy, mechanics, steam, and mechanical drawing, and an early aptitude for chemistry resulted in his making rapid progress at the works. His first responsible appointment was as assistant manager of the steel department at the Rhymney Works, and eventually he became manager. Later he was engaged in the London office of his uncle, who was a civil and mining engineer in South Africa, and a former general manager for De Beers. In 1891 Mr. Jones was engaged by the late Sir Lowthian Bell to carry out experiments on the preliminary treatment of molten metal before use in the open-hearth furnace, and other experimental work. In 1894 he took charge of the Clarence Blast Furnaces, and in 1904 was appointed works' manager on the retirement of the late Colonel Charles Lowthian Bell, a position he held up to the time of his death.

Personal.

THE late Mr. J. Barnes, ship repairer, of Blundellsands, left £26,263.

DR. S. RIDEAL has been elected president of the Society of Public Analysts.

THE late Mr. John Kennedy, engineer, of Fellowes Road, Hampstead, N.W., left £37,982.

THE late Mr. D. Etchells, engineer, of Wolverhampton, left estate valued at £22,649 gross.

MR. S. SMITH has been appointed superintendent of the Royal Aircraft Factory, Farnborough.

THE gross value of the estate of the late Mr. W. G. Izard, engineer, of Blackheath, Kent, is £23,328.

MR. A. C. DORMAN, of Dorman, Long & Company, Limited, is the new High Sheriff for Yorkshire.

THE RIGHT HON. EARL OF HARROWBY and Mr. H. E. Carter have been elected directors of Alfred Hickman, Limited.

MR. F. BIGGIN, of Sheffield, has been elected president of the National Association of Heating and Domestic Engineers.

THE late Mr. R. Murray, for many years engineer and estate agent for the North-Eastern Railway Company, left £17,634.

THE gross value of the estate of the late Mr. J. Hollows, engineer, of Rochdale, is £10,009, of which £9,931 is net personalty.

A BARONETCY has been conferred upon the Right Hon. Ellis Jones Ellis Griffith, K.C., a director of the Mond Nickel Company, Limited.

THE late Lieut.-Colonel R. A. Hudson, D.S.O., a director of Robert Hudson, Limited, Gildersome Foundry, left estate valued at £51,870 gross.

THE gross value of the estate of the late Mr. Holroyd Chaplin, a director of the Birmingham Aluminium Casting (1903) Company, Limited, is £55,664.

SIR CHARLES A. PARSONS has accepted his election as vice-president of the recently inaugurated North-Eastern Section of the Junior Institution of Engineers.

MR. C. H. T. PELMEAR, formerly general manager of the National Projectile Factory, Mile-End, Glasgow, has taken up the position of general manager at the Arrol-Johnston Aero Engine Factory, Dumfries.

SIR WILLIAM ELLIS, Master Cutler of Sheffield, received recently from the King of Italy, through the Duke of Genoa, the honour represented by his appointment as an Officer of the Crown of the Order of Italy.

A PRESENTATION has been made by the staff and managers of Thomas Firth & Sons, Limited, Sheffield, to Captain Alec M. B. Firth, eldest son of Mr. Bernard A. Firth (chairman of the company) as a token of esteem on the occasion of his recent marriage.

MR. C. S. OWSTON has joined the board of the Chemical Engineering & Wilton's Patent Furnace Company, Limited. Mr. C. S. Owston is a director of Thos. Green & Son, Limited, Smithfield Iron Works, Leeds, and his father was at one time a managing director of the Chemical Engineering Company.

CAPTAIN JAMES HAMILTON, Royal Scots Fusiliers, has been mentioned in despatches and awarded the Military Cross. Before the war Captain Hamilton was assistant to the works manager of the Langloan Iron & Chemical Company, Limited, Coatbridge. He is the son of Mr. Robert Hamilton, manager of the blast-furnace and chemical departments of the Glengarnock Works, of David Colville & Sons, Limited.

MR. F. J. BLIGHT, who has been elected a Fellow of the Royal Society of Edinburgh, is a member of the Iron and Steel Institute, the Faraday Society, and other scientific and literary associations, and holds the Freedom of the City of London. Mr. Blight had early acquaintance with the iron and steel works of John Spencer & Sons, Ltd., and was trained as an architectural and engineering draughtsman with Mr. E. M. Whitaker, the architect to the Great Northern Railway. He is also chairman and managing director of Charles Griffin & Co., Ltd., technical publishers.

Trade Talk.

MESSRS. MORRISON, KEKEWICH & COMPANY have removed to 270, Gresham House, Old Broad Street, London, E.C.2.

A WINDING-UP ORDER has been made against Hall & Sons (Birmingham), Limited, Whitehouse Street, Aston, Birmingham.

A WINDING-UP order has been made against the Rochester Engineering Company, Limited, 56, Cannon Street, London, E.C.

THE NORTH OF ENGLAND METAL MERCHANTS' ASSOCIATION has decided to join the British Federation of Iron, Steel, Tinplate and Metal Merchants.

IT is rumoured that a Sheffield firm is anxious to take an interest in the Whitehaven Hematite Iron and Steel Company's property at Cleator Moor.

BAXENDALE & COMPANY, LIMITED, of Manchester, have appointed Mr. Tomlinson, of Marton, near Preston, as their agricultural machinery representative.

THE Governing Body have decided to alter the name of the Manchester School of Technology, so that in future it may be known as the College of Technology.

HANS RENOLD, LIMITED, have removed to Bush Lane Chambers, Cannon Street, E.C.4, in consequence of the Government having commandeered their Kingsway offices.

THE NOBLE ELECTRIC STEEL COMPANY, of Heroult, California, have now become ferro-alloy makers, being engaged on ferro-manganese, ferro-chrome, and ferro-silicon.

ARRANGEMENTS have been completed for starting a shipbuilding yard in Drogheda under the auspices of an English syndicate, Mr. Robertson being the managing-director.

A SCHEME is being promoted for the construction of a shipbuilding yard at Burntisland, and the preliminary arrangements are well forward. About seven acres have been taken.

G. A. HARVEY & COMPANY (LONDON), LIMITED, Greenwich Metal Works, Woolwich Road, London, S.E.7, have opened a City office at Suffolk House, 5, Laurence Pountney Hill, E.C.4.

THE Board of Trade has sanctioned the assignment of licences, permitting the British Barimar-Thermit Welding Company, Limited, to operate and exploit the Thermit welding process in Great Britain.

WE are informed that the proposed acquisition by Messrs. John Brown & Company, Limited, of a controlling interest in the Carnforth Hematite Iron Company (1915), Limited, has fallen through.

MESSRS. H BING and R. H. E. Capill, engineer and agents, Milburn House, Newcastle-on-Tyne, trading under the style of Bing & Capill, have dissolved partnership. Mr. Capill will continue the business.

THE LEA RECORDER COMPANY, LIMITED, have removed from Deansgate, Manchester, to the Burnside Works, Cornbrook Park Road, Cornbrook, Manchester. They, however, still retain their registered offices at Deansgate.

MALCOLM & ALLAN, LIMITED, of Glasgow, have been appointed sole selling agents in Scotland for the Automatic and Electric Furnaces, Limited, makers of the Wild-Barfield electric furnaces and steel hardening equipment.

THE partnership heretofore subsisting between Messrs. R. Armitage and F. Brook, ironfounders, Collett Street, Ripponden Road, Oldham, under the style of Armitage & Brook, has been dissolved. Mr. Armitage will continue the business.

THE Government having commandeered their temporary offices at Windsor House, Kingsway, W.C., the Paterson Engineering Company, Limited, have again been compelled to move, and have secured premises at 11, Southampton Row, W.C.1.

WITH reference to the announcement in a recent issue of the formation of the Spanish Babcock & Wilcox Company (Compañia Española Babcock y Wilcox) at Bilbao, we now find that the share capital is to be 20,000,000 pesetas (£800,000 at par exchange).

THE Sunderland Building Committee has passed plans for a large extension of the shop accommodation at Messrs. Richardsons, Westgarth & Company's Scotia Engine Works, and also for an extension of the Westmoor Engine Works in Back Florida Street, Pallion.

RECENTLY the works of the Darlington Forge Company, Limited, have been considerably extended for the manufacture of forgings and castings for marine and general purposes, and the company will be in a better position to meet the demand expected in shipbuilding at the end of the war.

MESSRS. C. P. WINCOTT, of Sheffield, have on order six 50-ton and one 60-ton steel-melting furnaces, three of which are going into Sheffield works, three into South Wales, and one for the North-East Coast. They have also in hand 16 15-ton forge furnaces and 34 gas-fired annealing and heating furnaces.

NOTICE is given that the Rule Committee of the Supreme Court have made Rules of Court under Section 1 sub-section (5) of the Non-Ferrous Metal Industry Act, 1918, and, on account of urgency, the Committee have certified that the rules should come into immediate operation as Provisional Rules.

AT a meeting of the members of the Staffordshire Iron and Steel Institute at Dudley on March 9, Mr. J. N. Kilby, of Sheffield, read a paper dealing mainly with the defects found in steel ingots, or products of such ingots, apart from those directly due to bad manipulation in the forge or during rolling.

WILLIAM COOPER & GOODE, LIMITED, are being voluntarily wound up, with Mr. T. D. Neal, 110, Edmund Street, Birmingham, as liquidator. A new company having the same name is being registered. It will be remembered that the business of the company was recently acquired by Elliotts Metal Company, Limited.

THE President of the Board of Trade has appointed Sir Dudley Stewart Smith, K.C. (chairman), Sir Harold Elverston, M.P., and Mr. H. J. Mackinder, M.P., to be a committee to examine all applications for licences under the Non-Ferrous Metal Industry Act, 1918, and to report to the Board of Trade thereon.

EMPLOYERS and employed in the Manchester engineering industry have formed an Engineering Council, the primary object of which is to provide facilities for personal intercourse between employers and workers, and to carry out constructive investigation and study of conditions and problems affecting the industry.

MR. ARTHUR M. SAMUEL, of Norwich, has, our Parliamentary correspondent states, been nominated by the Association of Chambers of Commerce, on the invitation of the Ministry of Reconstruction, a member of an informal Standing Committee to consider as speedily as possible the best means of summoning joint conferences and grouping trades for that purpose.

J. LORD, LIMITED, engineers and furnace constructors, of Stockport, have appointed Mr. Lees Hall, formerly superintendent of the Monometer Company, of Birmingham, as their works manager, and will now be in a position to accept orders for parts requisite for the Monometer furnaces. The company propose to develop largely the question of melting furnaces of various types. They have removed their registered offices from 40, St. Peters Gate, Stockport, to new offices adjoining their Crown Works, Viaduct Street, Stockport.

SANDERSON BROTHERS & NEWBOULD, LIMITED, announce that the negotiations referred to at the last annual meeting with regard to the disposal of the company's works at Darnall have resulted in a sale which is to be consummated after the war. Some cottages adjoining the works in Newhall Road have been purchased during the year, and now form part of the property of the company.

THE RICHMOND GAS STOVE AND METER COMPANY, LIMITED, have supplied the cooking and water-heating equipment for the dining rooms at the works of Vickers, Limited, Crossley Motors, Limited, Sir W.

G. Armstrong, Whitworth & Comany, Limited, Messrs. Dunlop, Austin Motor Company (1914), Cammell, Laird & Company, Limited, and the Partington Steel and Iron Company, Limited.

We understand that negotiations which have been in progress for some time were concluded last month between the Barrow Hematite Steel Company, Limited, and the Millom and Askam Hematite Iron Company, Limited, on the one part, and Dr. R. S. Mutch and Mr. Stanley Mutch on the other part, whereby the undertaking of the Camerton Coal Firebrick and Ganister Company has been acquired by the Millom and Barrow Companies as from February 28.

Plans have been passed by the Sheffield Corporation for extensions at the works of D. Doncaster & Sons, Limited, J. Robson & Sons, Hadfields, Limited, S. Osborn & Company, Limited, Vickers, Limited, John Holding & Company, John Shaw, Limited, G. Longden & Son, Sanderson Brothers & Newbould, Limited, John Brown & Company, Limited, Dunford & Elliott, Limited, T. Firth & Sons, Limited, Brown Bayley's Steelworks, Limited, and E. Allen & Company, Limited.

The Tees Conservancy Commission have approved the sale of about 81 acres of Tees foreshore for the extension of Smith's Dock Company's shipyard and ship repairing establishment. Upon the new site it is proposed to construct an extension of the shipyards and marine engine and boiler establishment. An adjoining site of 76 acres has been acquired by the Tees Furnace Company for ironworks extensions, while Bell Brothers, Limited, are negotiating for a site for extensions on the opposite bank.

By a Proclamation, dated February 26, the list of prohibited exports has been amended as follows:—Headings deleted—(a) Fireclay, and articles manufactured of fireclay, including firebricks; (c) pitch, and all mixtures, preparations and commodities of which pitch forms an ingredient. Headings added—(a) Fireclay, and articles wholly manufactured of fireclay, including firebricks; (c) pitch, and all mixtures, preparations and commodities of which pitch forms an ingredient, not otherwise specifically prohibited.

The organisation dealing with the issue of licences for the carrying on of building and construction work under Regulation 8E of the Defence of the Realm Regulation of July 12, 1916, hitherto stationed at 6, Whitehall Gardens, S.W.1, has been transferred from the control of the Ministry of Munitions to that of the Ministry of National Service. All communications relating to the work of this organisation should henceforward be addressed to the Director, Building Licences Section, Ministry of National Service, 54, Victoria Street, S.W.1.

During the last couple of months the character of the demand for furnace plant has materially changed. Whereas for the last two months of 1917 about 85 per cent. of orders received by the Davis Furnace Company, Luton, were for crucible furnaces for metal melting, for the first two months in this year the position is reversed, and now at least 80 per cent. of orders are for furnaces of the oven type, principally for heating steel billets and plant for tool-making purposes. The change serves to show the difficulties of heating specialists in endeavouring to forecast the probable class of demand for many weeks ahead.

In a lecture at the Royal Institution recently, Sir R. T. Glazebrook gave some particulars concerning the future of the National Physical Laboratory. From April 1 its property, now vested in the Royal Society, will be vested in the Imperial Trust for the Encouragement of Scientific and Industrial Research, and its income, including receipts from fees, will be vested in, and under the control of, the Committee of the Privy Council for Scientific and Industrial Research. It will be organised in eight different departments, each with its own superintendent and a large staff of scientific assistants and observers.

An order has been issued by the Ministry of Munitions to the effect that manufacturers of steam fittings may supply fittings, involving the use of a total weight of copper not exceeding 7 lbs., without the necessity of receiving a permit or certificate, provided that the applicant is able to send to his supplier a signed declaration as under:—"I certify that my Order, No. —, is for an urgent repair, and/or renewal, and is necessary for the continuity of my business." These declarations are to be retained by the supplier for inspection by the Ministry of Munitions, and if the applicant is unable to sign such a declaration, he must apply to the Priority Department, Ministry of Munitions, 1, Caxton Street, S.W.1, for a permit, stating his case fully.

The Ministry of Munitions have included "all bismuth-bearing ores and bismuth metal and alloys and salts derived or produced therefrom" as war material to which Regulation 30a of the Defence of the Realm Regulations applies. Returns as to stocks are to be made immediately to the Controller of Non-Ferrous Materials Supply, and every mineowner in the United Kingdom producing bismuth-bearing ores is to make returns as to output, deliveries, and stocks every month. Monthly returns are also to be made of all imports, and likewise the manufacture of any articles from bismuth metal or alloy. Where stocks do not exceed 56 lbs. of bismuth salts and 14 lbs. of bismuth metal or alloy, and are not intended to be used in connection with the manufacture or alloy of steel or other metal, no returns need be made.

A new company has been registered under the title of the E. W. Harvey Gas Furnace Company, Limited, the proprietors of which are the managers and staff of the Siemens regenerative gas furnace business carried on at 10, Queen Anne's Gate, Westminster, in the name of "Frederick Siemens, Successor to Sir William Siemens." The business was originally established in London by Sir William Siemens in 1856, with a British staff, and the new company, through its managing director, Mr. Ernest Wm. Harvey, having acquired the goodwill and assets of Frederick Siemens, is therefore now an all-British concern. The new proprietors have been for many years the sole responsible managers at Westminster of the Siemens furnace business in Great Britain, France, Belgium, Spain, Italy, Australia, India, Japan, and the Transvaal.

As the solution of the problem of industrial and commercial reconstruction depends almost wholly on the after-war relationships between capital and labour, a pamphlet has been issued giving some information as to what the National Alliance of Employers and Employed has already done, and is doing, to bring about that closer co-operation between the two parties which is so essential and urgent. Many well-known men in the commercial and trade union worlds are associated in this movement, which is gradually covering the country with a network of local joint committees of employers and employed. It is the belief of this Alliance that British industry can only be properly reconstructed by the parties directly concerned (the employers and the employed), and that the application to this and that branch of industry of schemes by this and that department of State is bound to bring about not reconstruction but confusion.

On March 2, the Council of the National Association of Industrial Chemists met in conference in Birmingham, and in the evening there took place an open meeting of chemists and metallurgists at the Birmingham and Midland Institute. The conference, which was private, was presided over by Mr. A. C. J. Charlier, London (President). Matters of organisation and policy were dealt with, and an executive was appointed as follows: Messrs. Hargest (Newcastle), Thomas (Scunthorpe), Blackwell (Birmingham), Harrap (London), Davison (Middlesbrough), and Russell (Sheffield). Mr. C. H. Newton (Wednesbury) presided at the meeting at the Midland Institute, which was well attended. Mr. E. J. Thackeray, Sheffield (national secretary), stated that the reports received showed that good progress was being made by the Association. Sections had been formed at London, Birmingham, Shef-

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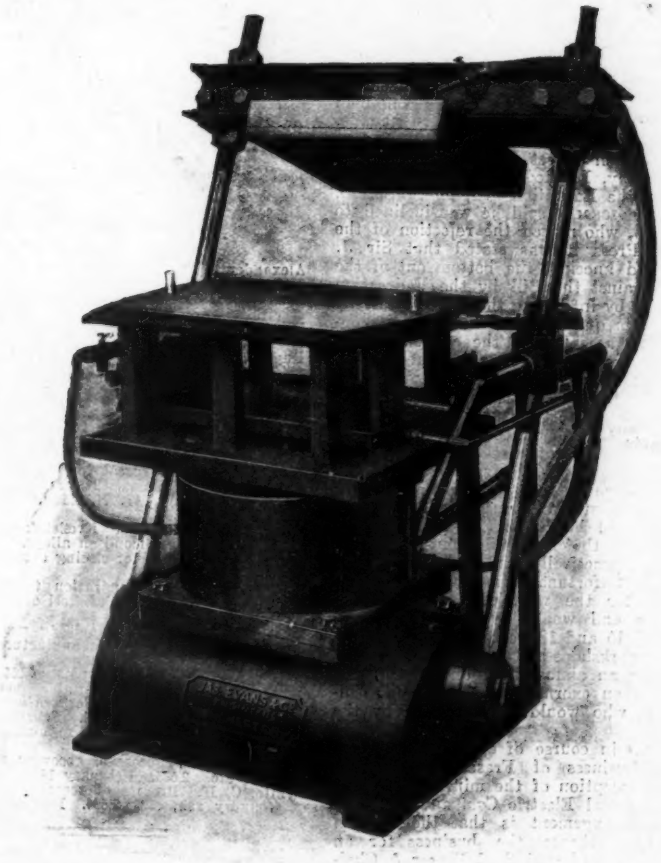

JAMES EVANS & CO., BRITANNIA WORKS,

BLACKFRIARS, **MANCHESTER.**

field, Middlesbrough, Newcastle, and Scunthorpe, and the membership was constantly growing. The aim was, by collective action, to advance the economic and social position of industrial chemists and metallurgists. Mr. Charlier, the President, also addressed the meeting.

For many years past, Dick, Kerr & Company, Limited, have occupied a leading position as contractors for the construction and equipment of electric railways and tramways, waterworks, factories, etc., with a general engineering works at Kilmarnock and large works at Preston for the manufacture of steam turbines, electrical machinery and electric lamps. Recently they have also taken over the control successively of the business of Willans & Robinson, Limited, of Rugby, builders of steam turbines and Diesel engines, and of the United Electric Car Company, Limited, of Preston, manufacturers of railway and tramway rolling stock; and, in addition, have completed a joint manufacturing and selling arrangement with the Phœnix Dynamo Manufacturing Company, Limited, of Bradford, in regard to certain classes of standardised electrical machinery. Some idea of the magnitude of the combined undertaking may be gathered from the fact that, roughly, 20,000 people are employed by the firm to-day, and that the combined capital involved amounts to some 1¾ million pounds. The general sales organisation will be concentrated at Abchurch Yard, Cannon Street, the head office of Dick, Kerr & Company, Limited.

In the debate on the Education Bill, on March 18, Brigadier-General Hickman said he was inclined to agree with Mr. Peto, who moved the rejection of the measure. In the Press it was stated that Sir J. Harmood-Banner had knocked the bottom out of the case put forward against the Bill by the Federation of British Industries by informing the House that the report which had been quoted was that of a sub-committee, and was not accepted by the council of the Federation. Those were not really the facts. The Federation was not generally in opposition to the Bill on principle, but it did not think the proposals set forth in the Bill were the best means to the end. In regard to compulsory attendance at continuation schools, the Federation thought that by the time that a boy had reached the age of 14 years, his teacher, the boy and his parents would be sufficiently acquainted with his prospects educationally and intellectually to know whether it would be better for him and his family and the country that he should continue school work or be learning practically and technically some trade. It would be unfortunate if, during the war and immediately after the war, when the greatest possible output was and would be wanted, if boys between the ages of 16 and 18 years were kept from the cotton-spinning workshops and from the coal mines. It was improper for an almost moribund Parliament to legislate on such an enormous scale without consulting the people who would be affected by the measure.

An arrangement is in course of completion for the acquisition of the business of Fraser & Chalmers, Limited, with the exception of the mining plant department, by the General Electric Company, Limited. The basis of the arrangement is that the General Electric Company purchases the business for an amount equal to the issued capital of Fraser & Chalmers, Limited, plus 25 per cent. The issued capital of the latter company is £441,000 in 378,000 ordinary and 63,000 preference shares of £1 each. The sum involved, therefore, would amount to approximately £551,250. There are, in addition, £100,000 6 per cent. first mortgage debentures of Fraser & Chalmers, Limited, in issue, secured by a specific charge on the gas engine works at Erith and by a general floating charge on the remaining assets of the company. The capital of the General Electric Company, Limited, is £1,400,000 in £10 shares, £600,000 being ordinary and £800,000 6 per cent. cumulative preference, and there are £100,000 ordinary and £100,000 preference still unissued. The company will retain the goodwill of its business in mining, milling, and metallurgical machinery, with manufacturing rights in respect thereof, and also its large merchanting business in South Africa and elsewhere, and its agencies for British and American manufacturers. The exact amount of the consideration for the sale, which is payable wholly in cash, cannot yet be ascertained, as it depends upon inventories of stocks, stores and work in progress, which was taken on March 31, as from when the transfer was to take place. The price will be arrived at on the following basis:—The buildings, plant, machinery and tools will be valued at the figures at which they stand in the books, after allowing for the usual depreciations. Stocks of materials, stores, and work in progress, other than mining machinery, will be valued on the basis ordinarily used for the purposes of annual stocktaking. The purchase price will include a large sum for the goodwill, patterns and drawings of the general manufacturing business, in respect of which no value has hitherto appeared in the accounts. The sale will accordingly increase the assets of the company to a material extent. It has been arranged with the purchasers that they will complete on account of the company all orders now in hand for mining machinery, and Fraser & Chalmers are also negotiating for the execution of new orders for mining machinery on terms to be agreed.

Applications for Patents.

Alexander, H. A., Imbery, A., and Vint, W. Hardening and tempering steel, etc. 3,825. March 5.
Arzano, C., and Clerici, G. Manufacture of iron by electrolysis. 3431 February 26. (Italy, March 19, 1917.)
Donald, R. Soldering aluminium or its alloys. 2,747. February 15
Dupont, P. Process and furnace for enamelling metal articles, etc. 2,667. February 14. (France, March 30, '17.)
Fairholme, F. C., and Hadfield, W. H. Refining molten metals in the process of manufacture. 3620. March 1.
Humbert, E. Process for making metals in electric furnaces. 3420. February 26.
Kenyon, J. Adjustable lifting bar for iron moulding boxes. 2,506. February 12.
Newman, T. F. Process for manufacture of rustless iron, and coating metals with other metals. 2,902. February 19.
Nichols Company, W. H. Moulding machine. 3416. February 26.
Norsk Hydro-Elektrisk Kvælstofaktieselskab. Connecting cast tubes of silicon-iron alloys. 3624. February 27.
Price, C. F. Means for closing casting, etc., furnaces. 3298. February 25.
Ramfield, A. E. Preparation to prevent penetration of carbon into portions of steel objects during case hardening. 2,823. February 18.
Smith, A. P. Foundry moulding machine. 3669. March 2.
Stobie, V. Electric steel manufacture. 3,970. February 20. February 13.
Tetley, W. Metal melting pots. 4,066. March 8.
Thermalloy, Limited. Ignitable metallic mixtures. 2,587.
Wade, H. (*Algoma Steel Corporation.*) Machines for breaking metallic bars. 2,444. February 11.
Walker, J. Mechanism for regulating electrodes of electric furnaces. 3,883. March 6.
White, C. H. Process of recovery of brass from foundry ash, etc. 2,653. February 14.
White, C. H. Process of recovery of brass and zinc from foundry ash, etc. 2,654. February 14.

Legal.

Judgment was given recently by Mr. Justice Lush on a point of law which affects a large number of munition workers. The question was whether a workman who left the factory at which he was employed by order of the Minister of Munitions was entitled to any accrued war bonus which he would have been entitled to had he remained in the same employment. His Lordship held that, as the transfer took place by the order of the Minister of Munitions, and not on the man's own initiative, the man was entitled to his share in any war bonus system which might be in existence up to the time of his leaving.

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Tough, Best Selected and Refined Ingots, Electrolytic Ingot Bars, Wire Bars, and Cathodes.

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All Brands Ingot and Bar Tin.

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New Companies.

Reflecto Metal Company, Limited.—Capital £50,000 in £1 shares.

New Fortuna Machine Company, Limited.—Capital £5,000 in £1 shares.

Weldon Engineering Company, Limited.—Capital £50,000 in £1 shares.

Fisher Chemical Engineering Company, Limited. —Capital £5,000 in £1 shares.

E. W. Harvey Gas Furnace Company, Limited.—Capital £8,000 in £1 shares.

Thomas-Knowles Metals Extraction (Wolverhampton). —Capital £3,000 in £1 shares.

Cleveland Twist Drill Company (Great Britain), Limited.—Capital £30,000 in £1 shares.

Morum & Company, Limited.—Capital £50,000 in £1 shares, to carry on the business of engineers.

Read-Westlake Company, Limited.—Capital £10,000 in £1 shares, to carry on the business of engineers.

High-Speed Tool Manufacturing Company, Limited.—Capital £3,000 in £1 shares. Registered office: 14-16, Shaftesbury Road, Acton.

David Sowden & Sons, Limited.—Capital, £25,000 in £1 shares, to take over the engineering business of David Sowden & Sons, Shipley.

F. J. Ballard & Company, Limited.—Capital £10,000 in £1 shares, to take over the business of an engineer carried on by F. J. Ballard at Tividale, Tipton.

Frickers Metal Company, Limited.—Capital £80,000 in £1 shares (21,500 preference). Registered office:—Langley Metal Works, Langley Street, Luton, Beds.

Boving Engineering Works, Limited. — Capital £70,000 in £1 shares (30,000 preference, and 40,000 ordinary). Registered office: Imperial Buildings, 56, Kingsway, W.C.2.

B. H. Gill & Son, Limited.—Capital £4,000 in £1 shares, to carry on the business of casters of brass, iron, etc. Registered office: Wallows Street, Round Oak, Brierley Hill.

Intercolonial Metal Company, Limited. — Capital £1,000 in £1 shares. The first directors are A. Parkes and E. T. B. Westmacott. Registered office: 314-16, Moorgate Station Chambers, E.C.2.

Valley Engineering & Metal Company, Limited.—Capital £3,000 in £1 and 1s. shares, to take over the existing business at Harpenden. The first directors are T. J. Cogawell and F. L. B. Locke.

B.E.R.A.C. Company, Limited.—Capital £1,000 in £1 shares, to carry on the business of constructional, manufacturing and general engineers, etc. Registered office:—Ham Wharf, Brentford, Middlesex.

William Parry, Limited.—Capital £1,000 in £1 shares, to take over the interests of W. Parry, carrying on business as a pump maker, iron and brass founder and engineer under his own name, and as the Dronfield Engineering Company.

Mee, Billing & Partners, Limited.—Capital £10,000 in £1 shares, to enter into an agreement with a company of the same name (in liquidation) and to carry on the business of iron, tinplate and metal manufacturers and merchants, etc. Registered office:—37, Lime Street, E.C.

William Cooper & Goode, Limited. — Capital £50,000 in £1 shares, to carry on the business of metal merchants, brass rollers, etc. The first directors are J. A. Kenrick, W. Chamberlain, A. Neville Chamberlain, E. E. Dendy, J. A. Kenrick, F. Platten, and T. W. Horton. Registered office: Bradford Street, Birmingham.

Redheugh Iron & Steel Company, Limited.—Capital £60,000 in £1 shares, to take over the business of the Redheugh Steel & Iron Company, and the Redheugh Firebrick Company, in Gateshead and elsewhere, and to enter into an agreement with D. S. Davies. The first directors are D. S. Davies (permanent governing director and chairman), and J. Gardner.

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SEND US YOUR ENQUIRIES FOR

are always successful in the struggle for the Mastery of the Air

Ventilation of Ships, Buildings and Mines, Induced Draught on Boilers, Dust Removal, High Pressure Fans for Forge Fires and Cupolas, Air Washers for Cooling and Purifying the Air, Fans for Removing Fumes or Steam, Steam Heater Units for Heating Factories and Workshops.

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Established 1863.

JAS. DURRANS & SONS,

Phœnix Works, Penistone, Near Sheffield.

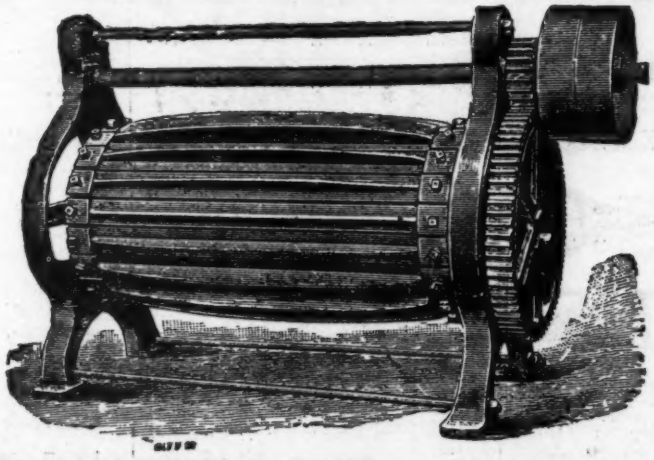
Manufacturers of all

FOUNDRY EQUIPMENTS

COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST

Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.

Improved Foundry Rattler or Fettling Drum.



These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.

The following testimonial explains itself :—

"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD.

MONTHLY PRICE LIST.

The undermentioned prices, unless otherwise specified, are those obtaining at the commencement of the current month.

CONTROL PRICES.

Pig-Iron.

	£	s.	d.
West Coast hematite, mixed Nos. 1, 2 and 3	6	7	6
Special under 0.03 P. & S... ..	6	15	6
„ „ 0.02 „	7	0	0
East Coast hematite, mixed Nos. 1, 2 and 3	6	2	6
Special under 0.04 P. & S. ..	6	7	6
Special under 0.03 P & S. ..	6	15	6
„ „ 0.02 „	7	0	0
Scotch hematite, mixed Nos. 1, 2 and 3..	6	2	6
Special under 0.03 P. & S. ..	7	10	0
Welsh hematite, mixed Nos. 1, 2 and 3	6	2	6
Special under 0.03 P. & S. ..	6	15	6
„ „ 0.02 „	7	0	0
HEMATITE—MALLEABLE—			
Refined—			
Refined Cupola Cast	8	0	0
Refined Cupola Cast to guaranteed analysis..	8	5	0
Cast direct from Blast Furnaces—			
Small Pig-Iron, all grades ..	7	10	0
Medium Pig-Iron White to Grey mottled	7	5	0
Medium Pig-Iron, all other qualities	6	17	6
Large Pig-Iron, all grades ..	6	17	6
Lincolnshire, basic or foundry ..	4	17	6
Cleveland, No. 1	4	19	0
„ other grades	4	15	0
„ basic	5	0	0
Northamptonshire, forge	4	7	6
„ fdy numbers	89/0		94/0
„ basic	4	17	6
Derbyshire, forge	4	10	0
„ foundry numbers	92/6		96/6
Derby & Notts. basic.	4	17	6
Leicestershire & Notts., forge ..	4	10	0
„ „ foundry nos.	92/6		96/6
North Staffs, forge	4	15	0
„ „ foundry	4	17	6
„ „ basic	4	17	6
South Staffordshire—			
Part mine forge	5	0	0
„ foundry	5	2	6
Common Staffordshire	4	15	0
All mine forge	5	15	0
„ foundry	6	0	0
Warm air forge	7	5	0
„ foundry	7	15	0
Lord Dudley's silicon	8	7	6
Cold blast	9	2	6
Basic	4	17	6
Scotch foundry and forge—			
Nos. 3, 4, and lower grades of Monkland, Dalmellington, Eglinton, and Govan.. ..	5	14	0
Nos. 3, 4, and lower grades of all other brands	5	15	6

No. 1 quality in all cases to be 5s. per ton above these prices.

All per ton net, f.o.t. makers' works. Mers. Com. 1½%

In all districts 1s. extra may be charged for Basic cast in chills.

High-Speed Tool Steel.

The maximum prices for high-speed tool steel have been fixed as follows:—

Finished bars, 14% Tung. 3s. 8d.

Finished bars, 18% Tung. 4s. 5d.

Per lb. basis. Extras as per authorised list. These prices are net delivered buyers' works.

The fixed prices for scrap which must be returned to steel makers' works are as follows:—

Millings and Turnings	8d.
Bar Ends	9d.

Both per lb. net delivered steel makers' works.

Ferro-Alloys

Net, Delivered Sheffield steel works.

	£	s.	d.
Ferro chrome: 4/6% carbon. Basis 60%, scale 10s. per unit Per ton	—		
Ferro-chrome: 6/8% carbon. Basis 60%, scale 10s. per unit. Per ton	—		
Ferro-chrome: 8/10% carbon. Basis 60% scale, 10s. per unit Per ton	—		
Ferro-chrome: Specially refined, guaranteed maximum 2% carbon broken to small pieces for use in best quality crucible steels. Basis 60%, scale 22s. per unit. Per ton	—		
Ferro-vanadium: 33/40% Va., per lb. of Va. contained in the alloy	—		
Ferro-silicon: 45/50%. Basis 50%, 5s. scale per unit .. Per ton	—		
Ferro-titanium: 23/25%, per lb. carbonless..	—		
Ferro-molybdenum: 70/80% Mo. per pound of Mo. contained ..	—		
Ferro-phosphorus: 20/25%. Per ton	—		
Ferro-tungsten: 75% to 80% per lb. of metallic tungsten contained	—		
*Ferro-manganese 80%	26	10	0
„ export —	—		

* F.o.b. Liverpool.

Non-Ferrous Metals.

Copper.

	£	s	d.	£	s.	d
Standard, Cash	110	0	0	110	10	0
Three months	110	0	0	110	10	0
Electrolytic ..	125	0	0	121	0	0
Tough ..	123	0	0	119	0	0
Best selected ..	123	0	0	119	0	0

Tin.

Standard, Cash	316	0	0		—	
„ Three months	316	0	0		—	
English Ingots	319	10	0		—	
Bars	320	10	0		—	
Refined		—			—	

Spelter.

American ..	54	0	0	50	0	0
Specials.. ..		—			—	
Hard	45	0	0	46	0	0
British ..	56	16	0	57	0	0

Lead.

Soft Foreign (net)	29	10	0	28	10	0
English		—			Nom.	

Antimony.

Regulus		—		85	0	0

Aluminium.

Virgin Metal 98/99% per ton	—		—

Phosphor Bronze.

INGOTS.	Per ton.
Alloy No. I. or II	—
III., IV. or V.	—
VI. or VII.	—
VIII.	—
XI.	—
Cast Strips and Ingots..	—
CASTINGS.	Per lb.
I. or II.	—
III. IV. o V.	—
VI. or VII	—
VIII.	—
XI.	—
No. VII., Chill, Cast, Solid ..	—
„ Cored Bars	—
Delivery 2 Cwt. free to any town.	
10 per cent. Phosphor Copper ..	£50 above price of best selected copper.
15 per cent. Phosphor Copper ..	£70 above price B.S.
Phosphor Tin (5 per cent.) ..	£30 above price of English Ingots.

(Phosphor-bronze prices supplied by CHARLES CLIFFORD AND SON, LIMITED, FARLEY STREET MILLS, BIRMINGHAM)

***Chromium (Metallic).**

98/99% purity, per lb.	—		—

***Nickel.**

In cubes, 98/99% purity Per ton	—		

Nickel Silver.

	per lb.
Ingots for raising	—
Ingots for Spoons and Forks ..	—
„ rolled to spoon size ..	—

***Tungsten Metal Powder.**

96/98% purity.. per lb. ..	—

***Molybdenum Metal.**

98/98% purity.. per lb. ..	—

***Cobalt Metal.**

97% purity .. per lb. ..	—

Quicksilver.

75 lb. bottle	—

* Net, Delivered Sheffield Works.

Scrap Iron and Steel.

Cleveland.

	s.	d.	s.	d.
Steel scrap, heavy melting..	—		—	
Iron scrap cast (cupola metal)	—		—	
London (f.o.b.).				
Heavy steel			105	0
Light „			55	0
Heavy cast			95	0
Control Prices.				
Heavy Steel Melting Scrap 105	0		125	0
Steel Planings, Turnings and Borings			65	0
Steel Planings, Turnings and Borings mixed with Wrought Iron, &c.			50	0
Steel Scrap, all other Classes ..			95	0
Wrought Iron Scrap			125	0
Ditto, mixed with Steel			95	0
W.I. Planings, Turnings and Borings mixed with Steel, &c.			50	0

Per ton delivered Buyers' Works.

Non-Ferrous Scrap.

London merchants quote the following prices for scrap metal, delivered London, and subject to market fluctuations:—

	A. Joseph. £	s.	d.
Hy. Electrolytic Copper Scrap ..	—		
Hy. Selected Scrap Brass ..	—		
Hy. Tinned Copper Wire	—		
Best Selected Gunmetal Scrap ..	—		
Re-melted Ingot Lead	—		

Stocks.

Metals.	Tons.
Copper, Europe and afloat	—
Tin, London, Holland, U.S.A. and afloat	20,007

Coke.

Middlesbrough.

	s.	d.	s.	d
Gas Coke	35	0	—	
Foundry	45	0	—	
Glasgow.				
Foundry Coke	—		45	0
Furnace Coke	35	0	—	
Gas Coke	—			
London.				
Welsh or Durham Foundry, d/d London Stations in truck	45	0	53	0
Ditto, d/d Birmingham Stations	44	0	46	0
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All per ton net. f.o.t. ovens.

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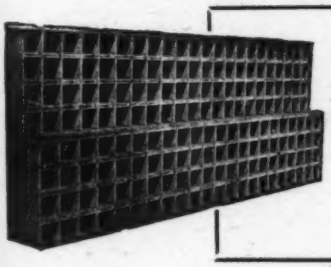

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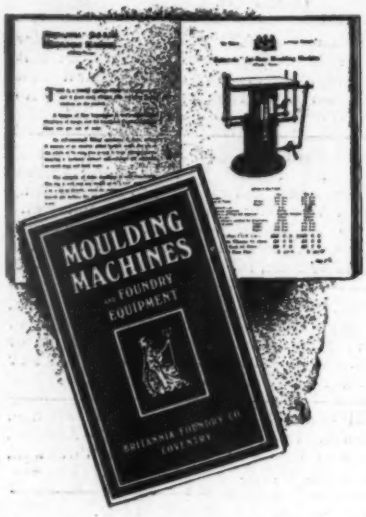

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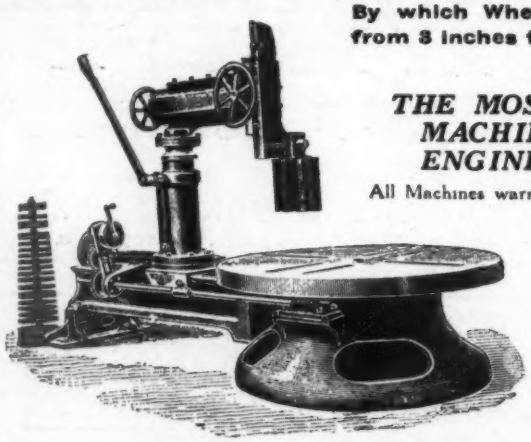

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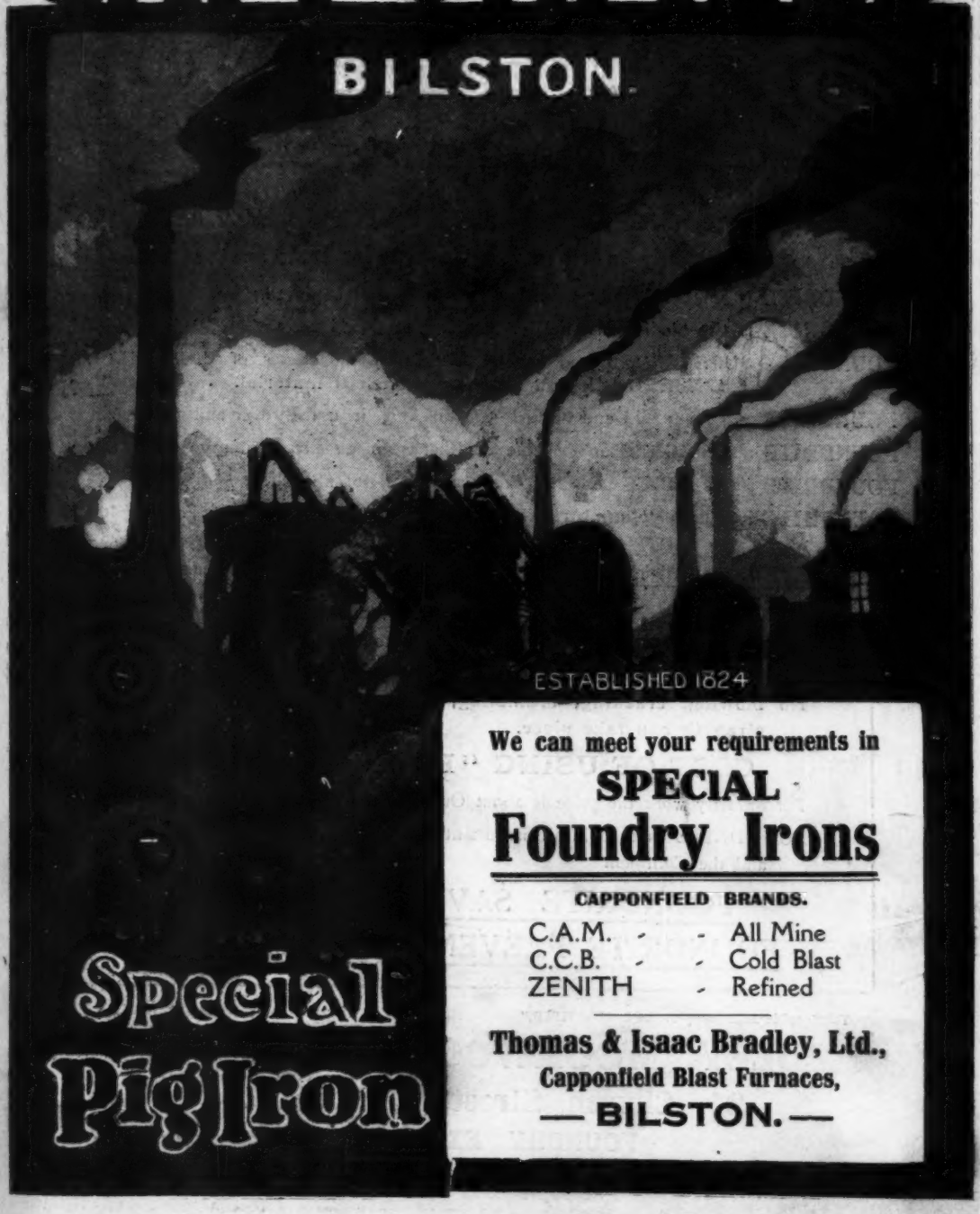

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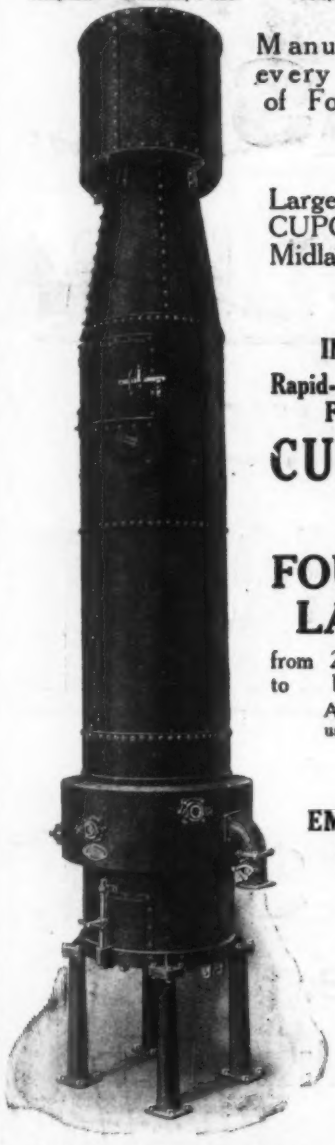

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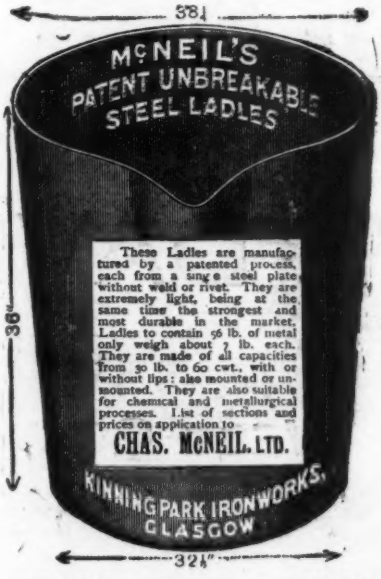
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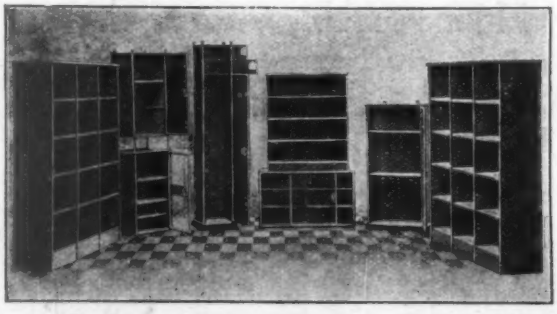

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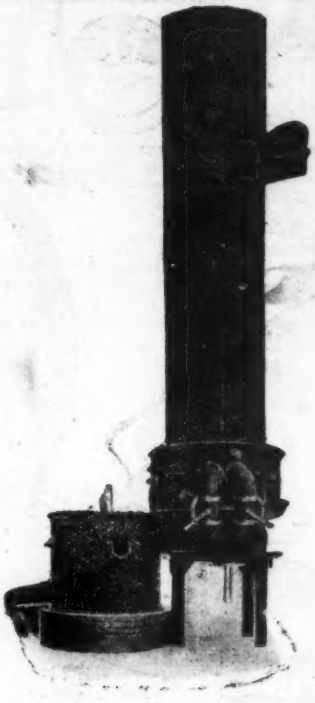

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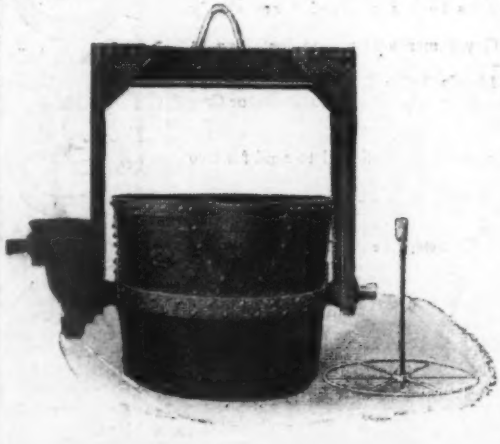

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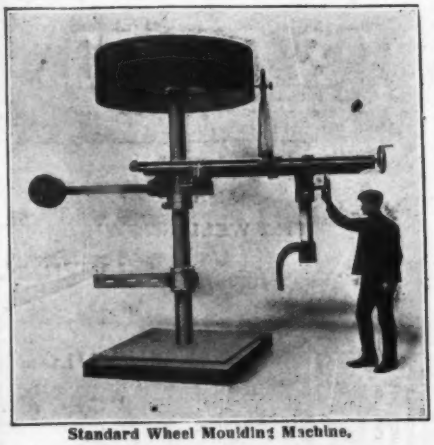

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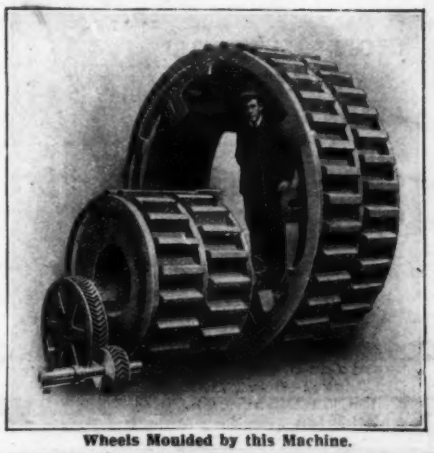

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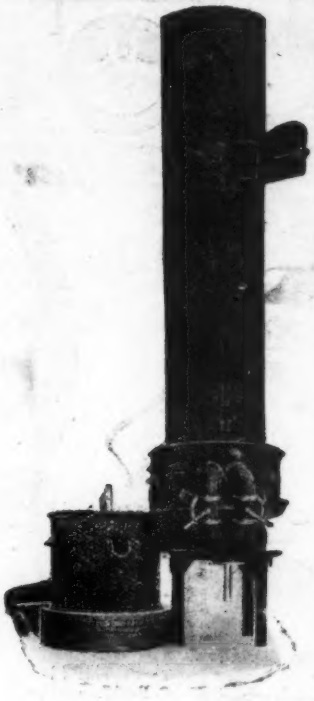

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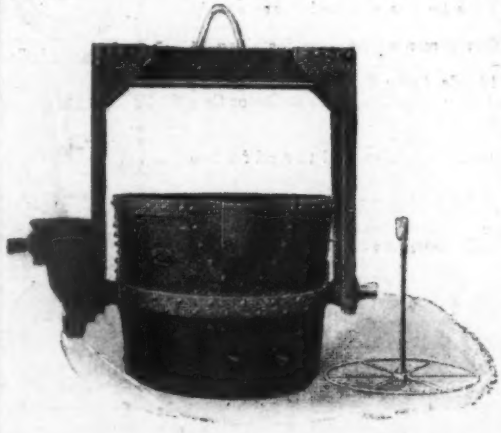

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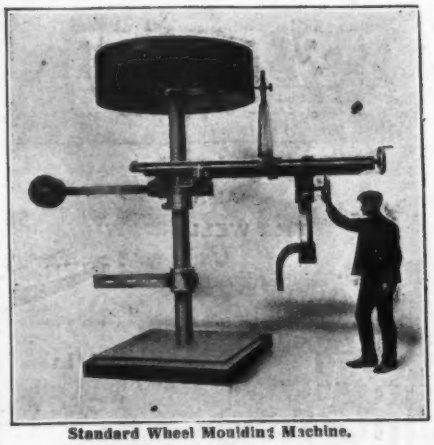

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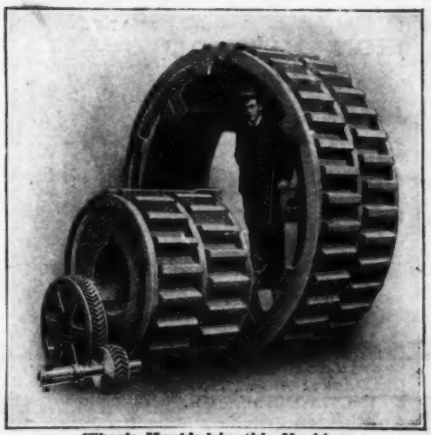

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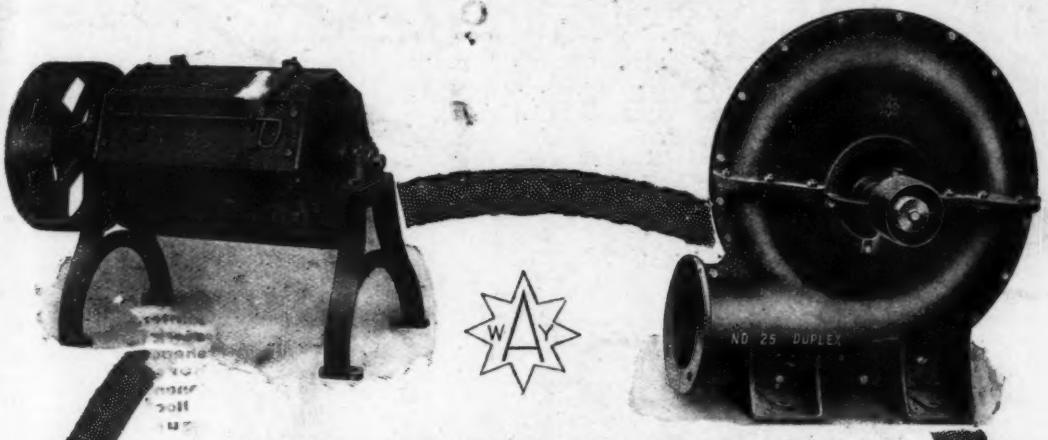

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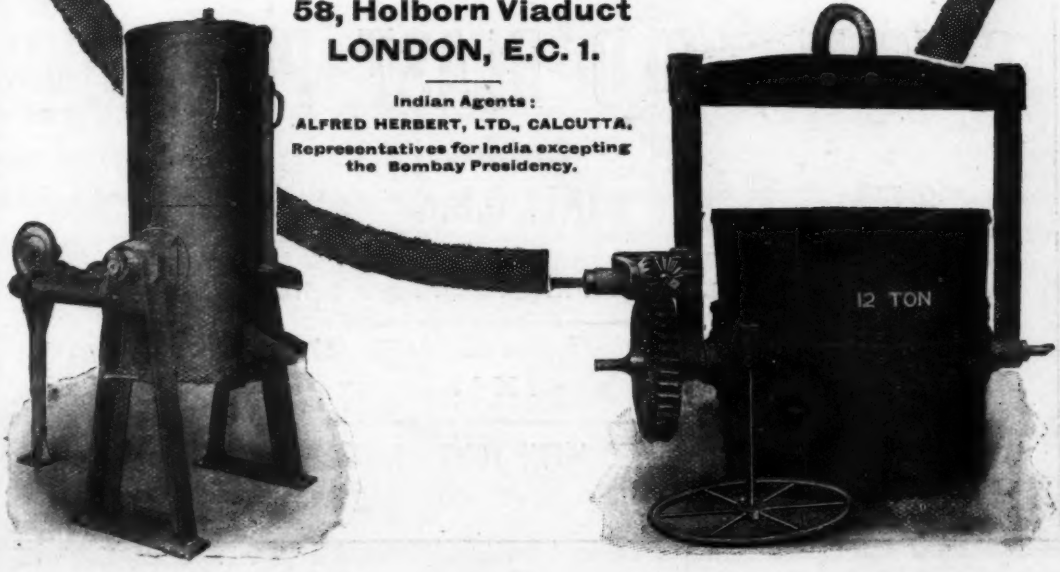

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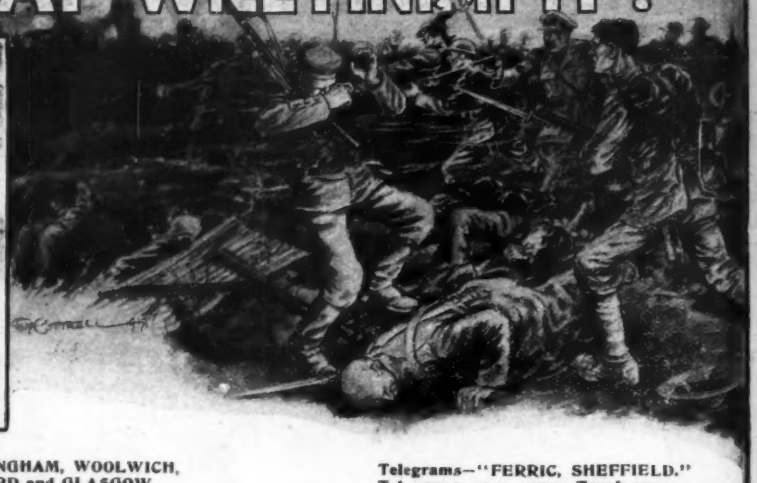

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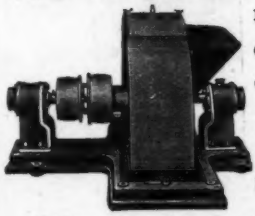

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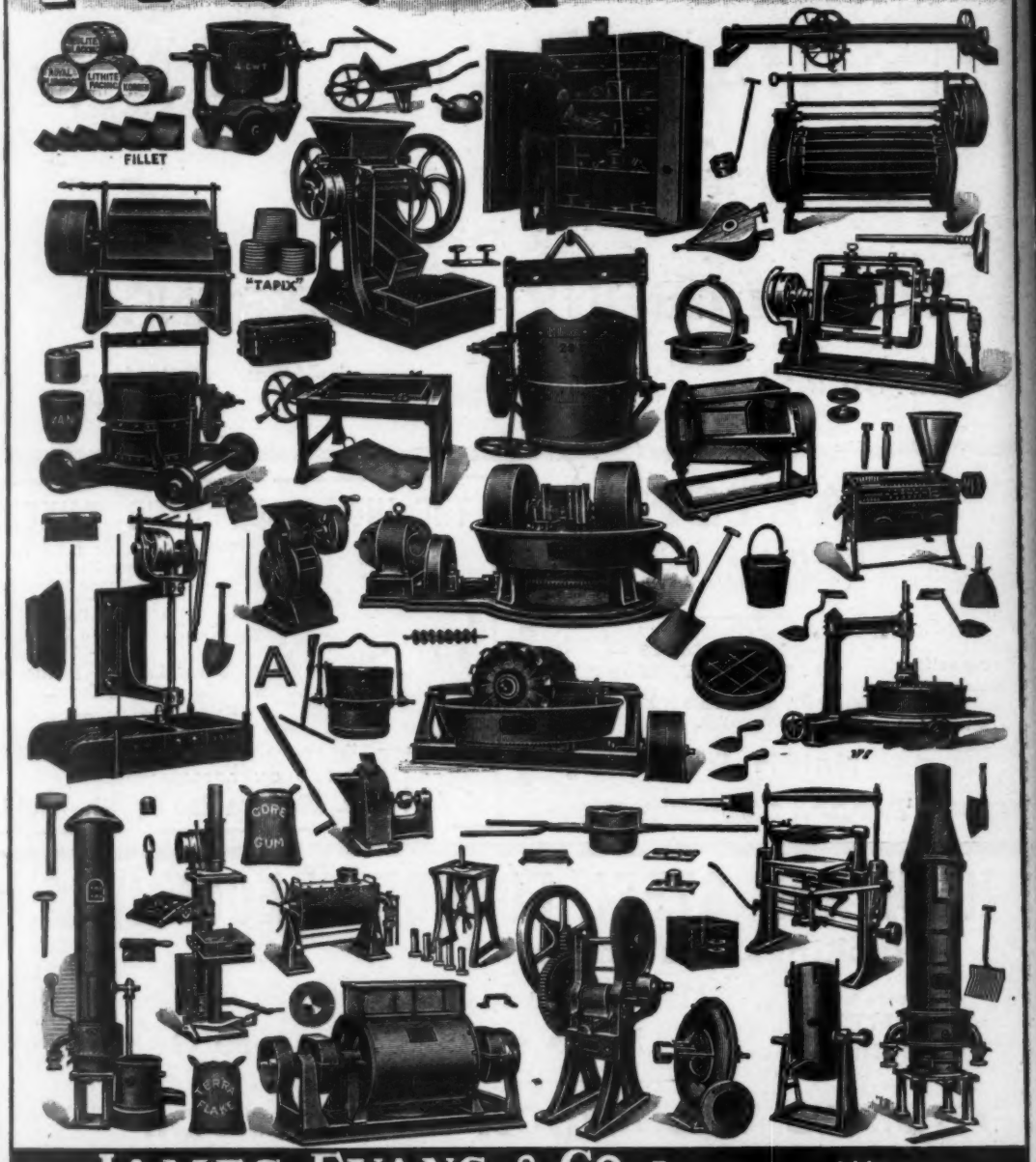

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